KPK BOARD NOTES

CHEMISTRY

9TH CLASS

Presented by:

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CHAPTER

1 FUNDAMENTALS OF CHEMISTRY

Introduction (تعارف):

The modern world in which we live is the world of chemicals. For example plastic, rubber, nylon, medicine, ink, paper, paint, dyes, polish etc. We all depend upon different chemicals which are necessary for our survival (بقا).

Chemistry is the study of nature of matter and the ways in which different forms of matter combine with each others. The development of chemistry has provided us a lot of facilities and serving (خدمت کرنا) the humanity and nature. Chemistry has a wide application in our daily life. Various examples are petrochemicals, medicine, drugs, papers, plastics, paints, colour pigments, soap and detergents. The study of chemistry also provides knowledge and techniques to improve our health and environment and to explore and conserve the natural resources.

Q1: Explain the history of chemistry.
کیمسٹری کی ابتدائی تاریخ کی وضاحت کریں۔

Ans. Muslim Period 600-1600 AD:

The science of chemistry grew and flourished in

early civilization of the world. The Egyptians (مصری), the Greeks (یونانی), the Romans (رومی) and the Muslims contributed much to the science of chemistry. The Muslims made a rich contribution to the knowledge of chemistry. They spread like shining stars on the horizon of the world of science. They made effective and valuable services in the field of chemistry. This period of Muslims is almost 1000 years long. The principal goals of the Muslims chemists were:

- To find out methods to prolong life
- Looking for ways to change base metals such as lead into gold.
- To find physical evidences (ثبوت) to support religious and philosophical beliefs.

Although they failed in doing so but they laid the foundation of the laboratory methods. These methods are still used in the modern chemistry. The Muslim scientists discovered many elements e.g. Arsenic (As), Stabium (Sb) and Bismuth (Bi) etc. They invented instruments like beakers, funnels, crucible, furnaces and retorts. Similarly many new chemical procedures were also introduced by the Muslim scientists like filtration, fermentation and distillation. The period of Muslims is generally called the period of "Alchemists" in the history of chemistry. Muslim scientists presented chemistry as purely experi-

mental science. Some famous Muslim scientists and their achievements are mentioned here:

1. **Jabber Ibn Hayyan (721-803 AD):**
(BISE Kohat 2019)
Jabber Ibn Hayyan is generally known as the father of chemistry. He was probably the first scientist who had a well established laboratory. He invented experimental methods such as distillation, sublimation, filtration and extraction of metals. He prepared hydrochloric acid (HCl), nitric acid (HNO_3) and white lead.

2. **Muhammad Ibn-e-Zakariya Al-Razi (864-930):**
Al-Razi was a physician, chemist and a philosopher. He wrote 26 books. The most famous book was "Al-Asrar". In this book he discussed the different processes of chemistry. He was the first chemist who divided the chemical compounds into four types. He also divided the substances into living and non-living origin. He prepared alcohol by fermentation process.

3. **Al-Beruni (973-1048):**
Al-Beruni contributed in the field of physics, meta-physics, mathematics, geography, astronomy and history. In the field of chemistry he understood the different chemical procedures and chemical combinations. He determined the densities of different substances.

ختم نبوت ﷺ زندہ باد

عظمت صحابہ زندہ باد

السلام علیکم ورحمۃ اللہ وبرکاتہ:

معزز ممبران: آپ کا وٹس ایپ گروپ ایڈ من "**اردو بکس**" آپ سے مخاطب ہے۔

آپ تمام ممبران سے گزارش ہے کہ:

- گروپ میں صرف PDF کتب پوسٹ کی جاتی ہیں لہذا کتب کے متعلق اپنے کمنٹس / ریویوز ضرور دیں۔ گروپ میں بغیر ایڈ من کی اجازت کے کسی بھی قسم کی (اسلامی و غیر اسلامی، اخلاقی، تحریری) پوسٹ کرنا سختی سے منع ہے۔
- گروپ میں معزز، پڑھے لکھے، سلجھے ہوئے ممبرز موجود ہیں اخلاقیات کی پابندی کریں اور گروپ رولز کو فالو کریں بصورت دیگر معزز ممبرز کی بہتری کی خاطر ریموو کر دیا جائے گا۔
- کوئی بھی ممبر کسی بھی ممبر کو انباکس میں میسیج، مس کال، کال نہیں کرے گا۔ رپورٹ پر فوری ریموو کر کے کاروائی عمل میں لائے جائے گی۔
- ہمارے کسی بھی گروپ میں سیاسی و فرقہ واریت کی بحث کی قطعاً کوئی گنجائش نہیں ہے۔
- اگر کسی کو بھی گروپ کے متعلق کسی قسم کی شکایت یا تجویز کی صورت میں ایڈ من سے رابطہ کیجئے۔
- سب سے اہم بات:

گروپ میں کسی بھی قادیانی، مرزائی، احمدی، گستاخِ رسول، گستاخِ امہات المؤمنین، گستاخِ صحابہ و خلفائے راشدین حضرت ابو بکر صدیق، حضرت عمر فاروق، حضرت عثمان غنی، حضرت علی المرتضیٰ، حضرت حسنین کریمین رضوان اللہ تعالیٰ اجمعین، گستاخ اہلبیت یا ایسے غیر مسلم جو اسلام اور پاکستان کے خلاف پراپیگنڈا میں مصروف ہیں یا ان کے روحانی و ذہنی سپورٹرز کے لئے کوئی گنجائش نہیں ہے لہذا ایسے اشخاص بالکل بھی گروپ جوائن کرنے کی زحمت نہ کریں۔ معلوم ہونے پر فوراً ریموو کر دیا جائے گا۔

- تمام کتب انٹرنیٹ سے تلاش / ڈاؤنلوڈ کر کے **فری آف کاسٹ** وٹس ایپ گروپ میں شیئر کی جاتی ہیں۔ جو کتاب نہیں ملتی اس کے لئے معذرت کر لی جاتی ہے۔ جس میں محنت بھی صَرف ہوتی ہے لیکن ہمیں آپ سے صرف دعاؤں کی درخواست ہے۔
- عمران سیریز کے شوقین کیلئے علیحدہ سے عمران سیریز گروپ موجود ہے۔
- **لیڈیز کے لئے الگ گروپ کی سہولت موجود ہے جس کے لئے ویریفکیشن ضروری ہے۔**
- اردو کتب / عمران سیریز یا سٹڈی گروپ میں ایڈ ہونے کے لئے ایڈ من سے وٹس ایپ پر بذریعہ میسیج رابطہ کریں اور جواب کا انتظار فرمائیں۔ برائے مہربانی اخلاقیات کا خیال رکھتے ہوئے موبائل پر کال یا ایم ایس کرنے کی کوشش ہر گز نہ کریں۔ ورنہ گروپس سے تو ریموو کیا ہی جائے گا بلاک بھی کیا جائے گا۔

نوٹ: ہمارے کسی گروپ کی کوئی فیس نہیں ہے۔ سب فی سبیل اللہ ہے

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اللہ تبارک تعالیٰ ہم سب کا حامی و ناصر ہو

4· **Ibn-e-Sina (980-1037):**

Ibn-e-Sina is generally known as the Aristotle of the Muslims world· He is famous for his contributions in the fields of medicine, mathematics, astronomy, medicinal chemistry and philosophy· He is the first scientist who rejected, the idea, that base, metals can be converted into gold· He wrote more than 100 books· These books were taught in the Europe for centuries·

Q2: Define chemistry· Explain various branches of chemistry· کیمسٹری کی تعریف کریں اور مختلف شاخوں کی وضاحت کریں۔

Ans· Chemistry:

(Malakand 2018, Peshawar 2019, Bannu 2019)

Definition: "The branch of science which deals with the study of matter, composition of matter, structure of matter, properties of matter, changes occurring in matter and the laws and principles which govern these changes is called chemistry·"

Branches of Chemistry:

The field of chemistry is very vast (وسیع)· To cover all the areas of chemistry, it is well divided into different branches· The main branches of chemistry are as follow:

1· **Physical Chemistry:**

"The branch of chemistry which deals with the study of physical properties of matter and the laws and principles that explain the changes in

matter and energy is called physical chemistry."

2. **Organic Chemistry:**

"The branch of chemistry which deals with the study of hydrocarbons and their derivatives is called organic chemistry."

3. **Inorganic Chemistry:**

"The branch of chemistry which deals with the study of elements and their compounds except hydrocarbons, carbon and their derivatives is called inorganic chemistry."

4. **Analytical Chemistry:**

"The branch of chemistry which deals with the qualitative (معیاری) and quantitative (مقداری) analysis (تجزیہ) of matter is called analytical chemistry."

Qualitative analysis means the amount of each atom or molecule in the given sample.

Quantitative analysis means the kind of atoms or molecules present in the given sample.

5. **Industrial Chemistry:**

"The branch of chemistry which deals with the study of various techniques and chemical processes used for the preparation of different industrial products like cement, glass, plastic and fertilizers is called analytical chemistry."

6. **Nuclear Chemistry:**

The branch of chemistry which deals with the study of nucleus, changes occurring in the nuc-

leus, properties of the particles present in the nucleus and the emission or absorption of radiations from the nucleus is called nuclear chemistry."

7. Biochemistry:

The branch of chemistry which deals with the study of synthesis, composition, decomposition and chemical reactions of substances which takes place inside the bodies of living organisms is called biochemistry."

8. Environmental Chemistry:

The branch of chemistry which deals with the study of various chemical substances present in the environment and their effect on humans life, animals and plants life is called environmental chemistry."

9. Electrochemistry:

It deals with the study of inter-conversion of electrical and chemical energies.

10. Thermo-chemistry:

It deals with the study of the amount of heat evolved or absorbed during a chemical reaction.

Q3: Define and explain basic terms used in chemistry. کیمسٹری میں استعمال ہونے والے بنایدی لغات کی وضاحت کریں۔

Ans. Basic Definitions:

Matter:

"Anything having mass and occupy space is called

matter."

Examples are: chair, pen, desk, bench etc.

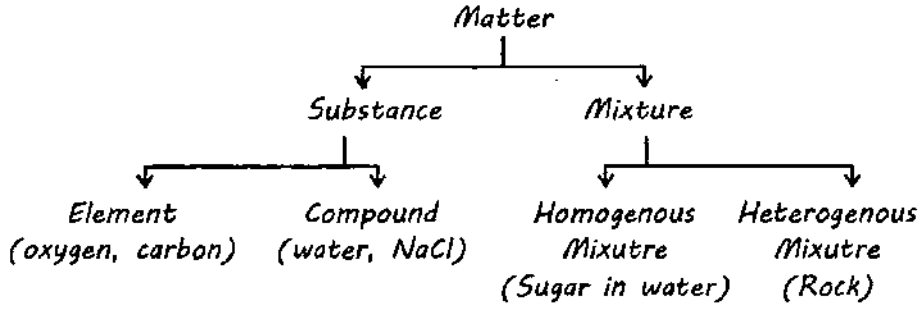
Mass:

"The quantity of matter contained in a body is called mass."

Substance:

"A piece of matter in pure form is called a substance." A substance is a word used to describe the type of matter which has definite properties and composition.

Example: Water is an example of substance because all samples of pure water obtained from different sources have exactly the same composition and properties. Classification of matter is given below:



In 1924 De-Broglie put forward the theory of dual nature of matter. He said that matter posses both the properties of waves and particles. He said that these two systems could not remain detached from each others. He mathematically proved that every moving object is attached with waves and every wave has particle nature as well.

Element:

"A substance composed of chemically similar atoms is called an element." Chemically similar atoms mean, atoms having the same atomic numbers.

Definition 2:

"A pure substance which cannot be split up into other simpler substances by any ordinary physical or chemical processes is called an element."

There are approximately 118 elements. Among them 92 are natural and the remaining have been prepared artificially in the laboratories. Elements are made up of small particles called atoms.

Atom: (Mardan 2018)

Definition: "The smallest particle of an element that can take part in a chemical reaction is called an atom." Atoms of a particular element are same to each others but different from the atoms of other elements.

Symbols of Elements:

Definition: "An abbreviation used for the chemical name of an element is called a symbol."

"The shortest name of an element is called a symbol."

In 1814, Berzelius suggested the system for representing elements with symbols. In most cases, the 1st letter of the name of an element is

taken in capital letter as the symbol.

Name of Element	Symbol
Hydrogen	H
Boron	B
Carbon	C
Nitrogen	N
Oxygen	O
Fluorine	F
Sulphur	S
Phosphorus	P

In some cases where the 1st letter has already been used, then the 1st letter is capital together with a small any other letter from its name are used. Similarly if different names of the elements start from the same word, then second word (small letter) is written for differentiation.

Name	Symbol	Name	Symbol
Aluminum	Al	Cobalt	Co
Magnesium	Mg	Chromium	Cr
Calcium	Ca	Barium	Ba
Cerium	Ce	Beryllium	Be
Cesium	Cs	Bismuth	Bi
Cadmium	Cd	Bromine	Br
Chlorine	Cl	Berkelium	Bk

Some element's symbols start with their Latin or Greek language name. Examples are:

English Name	Latin/Greek Name	Symbol
Antimony	Stibium	Sb
Copper	Cuprum	Cu
Gold	Aurum	Au
Iron	Ferrum	Fe
Lead	Plumbum	Pb
Mercury	Hydragyrum	Hg
Potassium	Kalium	K
Silver	Argentum	Ag
Sodium	Natrium	Na
Tin	Stannum	Sn
Tungsten	Wolfram	W

Scientific Informations:
The element Galium has a symbol of "Ga" atomic number "31" and mass number = 69·723· It is a soft metal and has silver colour· It never exists and found free in nature· It has some unique properties· For example it is so soft that it can be cut with knife· Its melting point = 29·76°C· So a lump (ڈلہ) of gallium, it would melt from the warmth of your hand·

Q4: Explain compound and mixture in detail· مرکب اور آمیزے کی وضاحت کریں۔

Ans· **Compound:** (Kohat 2019, Swat 2019)
Definition: "A new substance produced by the chemical combination of two or more different

elements in a fixed ratio by mass is called compound."

A compound is a pure substance. The properties of the compound are different from its constituent (اجزا) elements. For example, water is a compound. It is made up of two different elements hydrogen and oxygen. The ratio of hydrogen atoms to oxygen atom in water is always 2:1 by volume.

Similarly sodium chloride is also a compound. It is composed of 39.3% sodium and 60.7% chlorine by mass. A compound can only be converted into its elements by chemical methods.

Changing the ratio between atoms in a compound results in the formation of another compound. For example; adding one extra oxygen atom to water changes the ratio from 2:1 to 2:2 and the resulting compound will be H_2O_2 (hydrogen peroxide).

Formula of Compound:

A compound is always represented by a chemical formula. Chemical formula shows, symbols of the elements of which the compound is made and their combining ratio to each others. Some common compounds, their chemical names and formulae are given below:

Common Name	Chemical Name	Chemical Formula
Baking soda	Sodium bicarbonate	$NaHCO_3$

Bleaching powder	Calcium hypochloride	$CaOCl_2$
Caustic soda	Sodium hydroxide	$NaOH$
Chile salt petre	Sodium nitrate	$NaNO_3$
Lime stone	Calcium carbonate	$CaCO_3$
Lime water/ milk of lime or slaked lim	Calcium hydroxide	$Ca(OH)_2$
Magnesia	Magnesium oxide	MgO
Marsh gas	Methane	CH_4
Table salt	Sodium chloride	$NaCl$

Mixture:

Definition: "A material formed by the physical combination of two or more substances is called a mixture."

A mixture may consist of elements, compounds or both. The components of a mixture can be separated by physical methods. In a mixture the components retain (برقرار رکھنا) their original properties. The components of mixture are not mixed in fixed ratio.

Examples:

1. When sugar is dissolved in water, it form a mixture which is sweet in taste. The sweetness is due to the presence of sugar in water.
2. When iron pieces are mixed with powdered sulphur, a mixture is produced. Iron can be separated from this mixture by means of a

magnet. Similarly, in this mixture iron maintain its black colour and magnetic behaviour and sulphur retain its yellow colour.

3. Another example is alloy. Alloy is a homogeneous solid mixture of two or more than two metals or metals and non-metals. Its examples are: steel, brass, bronze, nichrome and solder.

Types of Mixtures: (Malakand 2018, Bannu 2019)

There are two types of mixtures i.e.

- Homogeneous mixture
- Heterogeneous mixture

1. Homogeneous Mixture:

Definition: "A mixture having uniform composition throughout its mass is called homogeneous mixture." For example; when common salt (NaCl) is dissolved in water, a homogeneous mixture is formed. Homogeneous mixtures are also called solutions.

2. Heterogeneous Mixture:

Definition: "A mixture having no uniform composition throughout its mass is called a heterogeneous mixture." In these mixtures one part has different composition than the other part. Here the distribution of components is non-uniform. Examples are; concrete is a heterogeneous mixture of rock, sand, cement and water. Rock and ice cream are also the examples of heterogeneous mixtures. Similarly salad, dirt, sand and water etc are other examples.

EXAMPLE 1·1: If we stir a teaspoon of sugar into a test tube of water and a teaspoon of sand into another test tube of water (dissolve), but the sand will not· Which mixture is a solution?

Solution:

When sugar is dissolved in water, it forms solution which is a homogeneous mixture· The sand and water forms a heterogeneous mixture· It is because particles of sand are visible in the mixture and do not distribute evenly throughout· On the other hand sugar particles are invisible even with a microscope·

PRACTICE PROBLEM 1·1: Making Mixtures:
Make mixtures of sand, baking soda, ink and oil in water·
Classify these are heterogeneous or homogeneous· Give reasons for your choice·

Solution:

- Mixture of sand and water is heterogeneous because sand particles are not distributed evenly·
- Mixture of baking soda and water is homogeneous because the particles of baking soda uniformly distribute in water and its particles cannot be seen with naked eye·
- Mixture of ink and water is homogeneous because components of ink are distributed uniformly and secondly cannot be seen

with naked eye.

- Mixture of oil and water will be heterogeneous because molecules of oil do not distribute uniformly in water and form separate layers when allowed to stand / rest.

Q5: Differentiate between mixture and compound. آمیزہ اور مرکب میں فرق واضح کریں۔

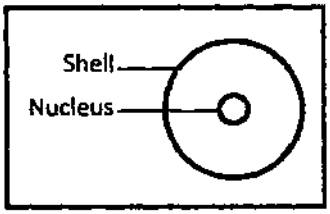
Ans. The main differences between mixture and compound are as under:

Compound	Mixture
1. It is formed as a result of chemical combination of atoms of elements.	It is formed by the physical combination or mixing up of substances.
2. The constituents of compound loses their original properties.	The constituents of mixture retain their original properties.
3. Compound has always fixed composition by mass.	Mixture does not have fixed composition by mass.
4. Components of the compound can be separated by chemical methods.	Components of mixture can be separated by physical methods.
5. Compound is represented by a chemical formula.	Mixture does not have any chemical formula because it consists of more components.

6· Compound has a homogeneous composition·	Mixture may be homogeneous as well as heterogeneous·
7· Compound has sharp and fixed melting point·	Mixture does not have sharp and fixed melting point·
8· Compound is the pure form of matter·	Mixture is the impure form of matter·
9· Chemical bond exists between components of the compound·	No chemical bond exists between components of the mixture·
Examples: H_2O, NaCl, KBr	Air, rock, concrete

Q6: What is atomic number and mass number?
ایٹمی نمبر اور کمیتی نمبر کی وضاحت کریں۔

Ans· **Atom:** (Swat 2019)
"The smallest particle of an element which can takes part in a chemical reaction is called an atom·"



Parts of an Atom:
There are two main parts of an atom· The central part is called nucleus and the extra nuclear part is known as shells / orbits / energy levels·

Sub-Atomic Particles:
According to the latest research atom has more than 100 sub-atomic particles· The particles of

which the atom is made are called sub-atomic particles. Some of these are electron, proton, neutron, meson, meo-meson, pion, kayons, hyperon, boson, nutrino, anti-nutrino and anti-proton.

Atomic Number (Z):

Definition: "The number of protons present in the nucleus of an atom is called atomic number." It is represented by "Z". The symbol of "Z" is taken from the German word "Zahl" which means "number". Atomic Zahl → atom number or atomic number.

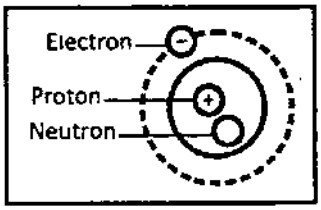
It has been found out that the atoms of one element differ from those of the other elements by the number of protons in their nuclei. No two elements have the same number of protons. We also know that atom is electrically neutral so the number of electrons must be equal to the number of protons. The number of neutrons in the atom of an element is different and cannot be used to characterize the atom. Therefore in periodic table elements are arranged on the basis of increasing atomic numbers i.e. number of protons. Some elements with their atomic numbers are given below:

Element	Symbol	At. #	Element	Symbol	At. #
Hydrogen	H	1	Beryllium	Be	4

Carbon	C	6	Boron	B	5
Oxygen	O	8	Nitrogen	N	7
Sodium	Na	11	Fluorine	F	9
Chlorine	Cl	17	Neon	Ne	10
Helium	He	2	Magnesium	Mg	12
Lithium	Li	3	Aluminum	Al	13

Mass Number (A) / Nucleon Number:

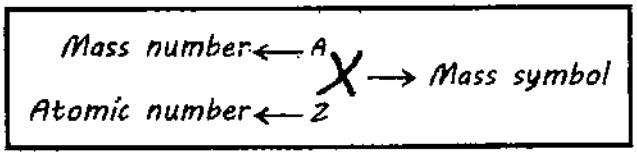
Definition: "The sum of the number of protons and neutrons present in the nucleus of an atom is called mass number." It is represented by "A". It is also called nucleon number. As protons and neutrons are relatively heavier particles than electron so, mass of an atom depends upon the number of protons and neutrons.



Mass number = proton + neutron

Hence the number of neutron can be calculated as,

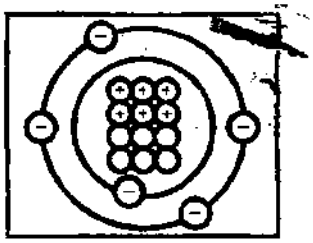
Number of neutron = mass number - atomic number



The superscript "A" represent mass number and the superscript "Z" represent atomic number.

EXAMPLE: Show/explain the atomic number, mass number and sub-atomic particles of carbon and oxygen:

Solution:



1. Atomic number of carbon
   = Z = 6
   Number of protons = 6
   Number of electrons = 6
   Mass number of carbon = A = 12
   Mass number = P + N = 6 + 6 = 12
   Symbolic representation of carbon = $_6C^{12}$
   Number of neutrons = A - Z = 12 - 6 = 6
2. Atomic number of oxygen = Z = 8
   Number of protons = 8
   Number of electrons = 8
   Mass number of oxygen = (A) = P + N
   A = 8 + 8 = 16
   Symbolic representation of oxygen = $_8O^{16}$
   Number of neutrons = A - Z = 16 - 8 = 8

TEST YOURSELF:

1. An atom of lithium has three protons and four neutrons in its nucleus.

a. **What is its atomic number and atomic mass?**

Ans. As we know that atomic number is the number of proton, so atomic number = 3. We also know that mass number is the sum of protons and neutrons so mass number = 3 + 4 = 7.

b. **How many electrons does it have?**

Ans. As the number of electrons in an atom is equal to the number of protons so lithium will contain 3-electrons.

2. **Atomic number of iron is 26 and atomic mass is 56.**

a. **How many protons and electrons does an iron atom have?**

Ans. As atomic number is 26, so the number of protons = 26 and the number of electrons = 26.

b. **How many neutrons does an iron atom have?**

Ans. Neutron = mass number = atomic number

Neutron = 56 - 26 = 30

3. **Do you know any element having no neutron in its atom?**

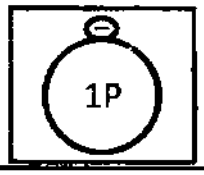
Ans. Yes I know an atom of hydrogen namely protium which has no neutron.

Protium = $_1H^1$ Atomic number (Z) = 1

Mass number (A) = 1

Neutrons = A - Z

Neutrons = 1 - 1 = 0



SCIENTIFIC KNOWLEDGE:

Isotopes: Atoms of the same element having the same atomic numbers but different mass numbers are called isotopes and this phenomenon is called isotopy. The difference in mass number is due to the difference in the number of neutrons.

Isotopes of carbon = C^6_{12}, C^6_{13}, C^6_{14}

Isotopes of oxygen = $_{16}O^8$, $_{17}O^8$, $_{18}O^8$

Q7: Explain the following terms: relative atomic mass, atomic mass unit and average atomic mass. درج ذیل لغات کی وضاحت کریں۔

Ans. Relative Atomic Mass: (Bannu 2019)

Definition: The relative atomic mass of an element is the mass of one atom of an element as compared to the mass of 1/12 the mass of C-12. (OR)

"The mass of one atom of an element as compared to the mass of 1/12 mass of the lightest isotope of carbon (C-12) is called relative atomic mass."

As we know that atom is very small and invisible. There is no sensitive balance to measure the mass of a single atom. It has been observed by x-rays work in the 20^{th} century that size of the atom is so small that it can be imagined by the following calculations:

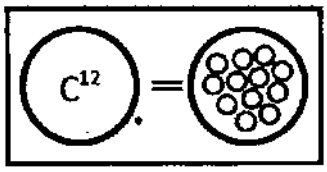
1. Its diameter is about 0.2nm.
2. A person breaths approximately (تقریباً) 10^5 million atoms in a deep breath (گہرا سانس 10=1 ملین)
3. If atoms are joined together in a line two million atoms will be required to cover a full stop (.).

Similarly the mass of an atom ranges from 10^{-24} grams to 10^{-22} grams. Therefore need was felt to express atomic masses by comparing them with a mass of standard atom. Carbon (C-12) atom was chosen as a standard for comparison. Carbon has the mass of exactly 12 units.

$^{12}C = 12$ units

One atom of carbon = 12 units

$1/12^{th}$ of the mass of C - 12 = 1



Atomic Mass Unit (a·m·u):

Definition: "The quantity of $1/12^{th}$ of C-12 is called atomic mass unit (a·m·u)·"

Atomic mass unit is the mass of the $1/12^{th}$ the mass of an atom of C-12· Atomic mass unit is the unit for atomic masses· It is abbreviated as amu· It is also called Dalton (Da)·

Relationship between amu and Gram:

1 mole carbon atoms = 12 grams

$6·023 \times 10^{23}$ carbon atoms = 12 grams

$$1\text{-carbon atom} = \frac{12}{6·023 \times 10^{23}} = 1·99 \times 10^{-23} \text{ gm}$$

1-carbon atom weights = $1·99 \times 10^{-23}$ g

12 amu weights = $1·99 \times 10^{-23}$ g

$$1 \text{ amu weights} = \frac{1·99}{12} \times 10^{-23} \text{ g}$$

1 amu weights = $0·167 \times 10^{-23}$ g

1 amu = $1·67 \times 10^{-24}$ grams $\Rightarrow$ $1·67 \times 10^{-27}$ kg

Relative Atomic Masses of Some Elements:

Element	Relative Atomic Mass
1· Hydrogen	1·0079 ≅ 1·008 amu
2· Oxygen	15·8994 ≅ 16 amu
3· Sodium	22·9897 ≅ 23 amu
4· Magnesium	24·3050 ≅ 24 amu
5· Silver	107·8082 ≅ 107·80 amu

Average Atomic Mass:

Average atomic mass is the weighted average of the atomic masses of the naturally occurring isotopes of an element.

Most of the elements have fractional atomic masses or decimal atomic masses. This is because most elements are composed of two or more naturally occurring isotopes and the relative abundance (فراوانی) of each isotope is counted.

Relative atomic masses depend upon:

1. Number of possible isotopes
2. Percentage/abundance of each isotope

Formula used to find out the average atomic mass of an element is given below:

$$\text{Average atomic mass} = \frac{(\text{Atomic mass of } 1^{st} \text{ isotope} \times \% \text{ abundance})}{100} + \frac{(\text{Atomic mass of 2nd isotope} \times \% \text{ abundance})}{100}$$

EXAMPLE:

The average atomic mass of chlorine is 35.5 amu. There are two isotopes of chlorine, one is Cl-35 and the other is Cl-37. The percentage of Cl-35 is 75% and the percentage of Cl-37 is 25%. So the average atomic mass of chlorine can be calculated as:

$$\text{Average atomic mass} = \frac{(35 \times 75) + (37 \times 25)}{100}$$

$$= \frac{2625 + 925}{100}$$

$$= \frac{3550}{100} = (35{\cdot}50\ amu)$$

PRACTICE PROBLEM 1·2:

Naturally occurring gallium consist of 60·108% Ga-69 with a mass of 68·9256 amu, and 39·892% Ga-71 with a mass of 70·9247 amu. Calculate the average atomic mass of gallium. Calculate the average atomic mass of neon from the given data:

$^{20}_{10}Ne$ = 90·51%, $^{21}_{10}Ne$ = 0·27% , $^{22}_{10}Ne$ = 9·22%

Solution:

i) Average atomic mass of Ga

$$= \frac{(68{\cdot}9256 \times 60{\cdot}108) + (70{\cdot}9247 \times 39{\cdot}892)}{100}$$

$$= \frac{(4142{\cdot}979) + (2829{\cdot}328)}{100}$$

$$= \frac{6972{\cdot}307}{100} = (69{\cdot}72)$$

ii) Average atomic mass of Ne

$$= \frac{(20 \times 90{\cdot}51) + (21 \times 0{\cdot}27) + (22 \times 9{\cdot}22)}{100}$$

$$= \frac{1810{\cdot}2 + 5{\cdot}67 + 202{\cdot}84}{100}$$

$$= \frac{2018{\cdot}71}{100} = \boxed{20{\cdot}19\ amu}$$

Q8: Stute and explain with examples:

درج ذیل کی وضاحت کریں۔

1· Chemical Formula 2· Empirical Formula

3· Molecular Formula

Ans· 1· **Chemical Formula:** (Kohat 2019)

Definition: "The symbolic representation of a mo-

lecule or a compound is called chemical formula." Chemical formula is an abbreviation used for the full name of a compound. The chemical formula of a compound is written by putting together the chemical symbols of the elements that make up the compound. Chemical formula gives us informations about;

1. Type of atoms [elements] present in the compound.
2. The ratio of different atoms present in compound.

For example;

Chemical formula of sodium nitrate = $NaNO_3$

Chemical formula of glucose = $C_6H_{12}O_6$

Types of Chemical Formula:

There are two main types of chemical formula:

1. Molecular Formula
2. Empirical formula

1. **Molecular Formula:** (BISE Malakand 2018, Abbottabad 2019)

"The type of chemical formula which shows the exact number of atoms of each element present in one molecule of that compound is called molecular formula." Molecular formula shows the composition of a molecule. Examples:

Molecular formula of glucose = $C_6H_{12}O_6$

Molecular formula of benzene = C_6H_6

2. **Empirical Formula:**

"The type of chemical formula which shows the

smallest whole number ratio of atoms / ions in a compound is called empirical formula."

The word "empirical" means experimental. The word "empirical" also means based on observations and experiments. An empirical formula always gives the correct ratio of the elements in the compound. For example:

The empirical formula of glucose is CH_2O.

The empirical formula of benzene is CH.

The empirical formula of acetylene (C_2H_2) = CH

The empirical formula of hydrogen peroxide (H_2O_2) = HO

Some Compounds with Molecular and Empirical Formula:

Name of Compound	Molecular Formula	Empirical Formula
Acetic acid	CH_3COOH →	CH_2O
Acetylene	$C_2H_4O_2$	CH
Benzene	C_2H_2	CH
Glucose	C_6H_6	CH_2O
Hydrogen peroxide	$C_6H_{12}O_6$	HO
Sulphuric acid	H_2O_2	H_2SO_4
Iron oxide	H_2SO_4	Fe_2O_3
Ammonia	Fe_2O_3	NH_3
Methane	NH_3	CH_4
Water	CH_4	H_2O
	H_2O	

Sometimes a molecule has the same empirical and

molecular formula. For example:

Methane:	CH_4 and CH_4
Water:	H_2O and H_2O
Ammonia:	NH_3 and NH_3
Carbon dioxide:	CO_2 and CO_2

A molecular formula may be the same or multiple of empirical formula.

Derivation of Molecular Formula:

Molecular formula is derived from empirical formula by the following relationship:

Molecular Formula:

$n \times$ Empirical formula

The value of "n" can be find out as:

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$$

EXAMPLE: The empirical formula of benzene is CH. The molecular mass of benzene is 78 amu. Find out its molecular formula.

Solution:

Empirical formula = CH

Empirical formula mass = 12 + 1 = 13amu

Molecular mass = 78amu

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{78}{13} = 6$$

Molecular formula = n(empirical formula)

$= 6(C_1H_1) \Rightarrow (C_6H_6)$

Formula Unit:

"The smallest repeating unit of an ionic compound is called formula unit."

Formula unit shows the simplest ratio between the ions present in a giant (جائنٹ / بڑا) structure. All the ionic compounds are represented by the formula unit. For example; NaCl is the formula unit of sodium chloride. In sodium chloride Na^+ ions and $\bar{C}l$ ions are present in 1:1 ratio. Similarly KCl is the formula unit of potassium chloride.

PRACTICE PROBLEM 1·3:

How many atoms of each element are present in one formula unit of each of the following compounds?

(a) Hg_2Cl_2 (b) $NH_4H_2PO_4$

(c) $MgCl_2$ (d) NH_4OH

Solution:

a. Number of atoms of each element in Hg_2Cl_2:

$Hg = 2$ $Cl = 2$

b. Number of atoms of each element in $NH_4H_2PO_4$:

$N = 1$ $H = 6$ $P = 1$ $O = 4$

c. Number of atoms of each element in $MgCl_2$:

$Mg = 1$ $Cl = 2$

d. Number of atoms of each element in NH_4OH:

$N = 1$ $H = 5$ $O = 1$

Q9: What is molecular mass of a compound and formula mass of a formula unit?

مالیکیولی ماس، فارمولا ماس اور اکائی فارمولا سے کیا مراد ہے؟

Mardan 2019, Peshawar 2019

Ans· **Molecular Mass:**

Definition: "The sum of the relative atomic masses of all the atoms present in a molecule is called molecular mass." Its unit is amu.

Molecular mass of a substance can be calculated by adding the relative atomic masses of all the atoms present in one molecule of that substance.

For example:.

Molecular formula of ethane = C_2H_6

Atomic mass of C = 12

Atomic mass of hydrogen = 1

Molecular mass =2(atomic mass of C) +6(Atomic mass of H)

= 2(12) + 6(1)

= 24 + 6 = 30 amu

Formula Mass:

Definition: "The sum of the relative atomic masses / ionic masses present in the formula unit of an ionic compound is called formula mass:"

For example, formula mass of NaCl can be calculated as:

Formula mass of NaCl=1(At.mass of Na) + (At.mass of Cl)

= 1(23) + 1(35.5)

= 23 + 35.5 = (58.5 amu)

EXAMPLE 1.2: Calculate the formula mass of:

(a) $(NH_4)_2SO_4$ (b) $Fe(NO_3)_2$

Solution:

(a) $(NH_4)_2SO_4$: $2N \rightarrow 2 \times 14 = 28$ amu

$8H \rightarrow 8 \times 1 = 8$ amu
$1S \rightarrow 1 \times 32 = 32$ amu
$4(O) \rightarrow 4 \times 16 = 64$
(132amu)

(b) $Fe(NO_3)_2$: $1Fe = 1 \times 56 = 56$amu
$2N = 2 \times 14 = 28$amu
$6(O) = 6 \times 16 = 96$amu

So formula mass = 180amu

PRACTICE PROBLEM 1·4:

Calculate the formula mass of:

(a) KCl (b) Na_2CO_3

Solution:

Formula mass of KCl = 39 + 35·5 = 74·5 amu

Formula mass of Na_2CO_3
$= (2 \times 23) + (1 \times 12) + (3 \times 16)$
$= 46 + 12 + 48 =$ 106amu

Q10: Explain chemical species in detail·
کیمیائی سپیشیز کی وضاحت کریں۔

Ans· **Chemical Species:**

Definition: "Atoms or group of atoms which take part in a chemical reaction are called chemical species:"

It may be neutral or it may carry a charge· Chemical species are classified into ions, free radicals and molecular ions·

Ions:

Definition: "The particles that carries a net electrical charge, positive or negative after gaining or

losing electrons are called simple ions." Ions are of two types:

a) Cations [Positive Ions]:

Definition: "The positively charged specie is called cation." It is formed after loss of electrons from the valence shell of an atom. Positive ions have always less number of electrons than the number of protons.

Examples:

Atoms	:	Cations	:	Electrons
H	$\longrightarrow$	H^+	+	$1\bar{e}$
Na	$\longrightarrow$	Na^+	+	$1\bar{e}$
Mg	$\longrightarrow$	Mg^{+2}	+	$2\bar{e}$

b) Anions [Negative Ions]:

Definition: "The negatively charged specie formed after gaining electrons is called anion." Negative ions [anions] always have more number of electrons than the number of protons.

Examples:

Atoms			
$F + 1\bar{e}$	$\longrightarrow$	F^{-1}	Fluoride ion
$Cl + 1\bar{e}$	$\longrightarrow$	Cl^{-1}	Chloride ion
$O + 2e\bar{s}$	$\longrightarrow$	O^{-2}	Oxide ion

Differences Between an Atom and Ion:

Atom	Ion
1. It is neutral. It has same number of protons and electrons.	1. It has a net charge. The number of protons is different than electrons.

2. It is the smallest particle of an element.	2. It is the smallest unit of an ionic compound.
3. It can or cannot exist freely.	3. It cannot exist freely.
Examples: Na, K, Fe	**Examples:** Na^{+}, K^{+}, Fe^{+2}, F^{-}, O^{-2}

Molecular Ions: (Mardan 2018)

Definition: "A molecular specie having positive or negative charge is called a molecular ion."

When a molecule loses or gains one or more electrons, it forms a molecular ion. Molecular ions can be cationic molecular ions or anionic molecular ions. Cationic molecular ions are more common than anionic molecular ions.

Cationic Molecular Ions:

CO^{+1}, O_2^{+1}, $C^{+1}H_4$, N_2^{+1}, SO_2^{+1}

Anionic Molecular Ions:

$C_2H_5O^{-1}$, SO_4^{-2}, PO_4^{-3}

Free Radical:

Definition: "A specie having an unpaired or odd number of electrons is called free radical." Actually free radicals are atoms or group of atoms that has a single [unpaired] electron in an outermost shell with no charge. It is represented by putting a dot over the specie. For example: $\dot{H}$, $\dot{Cl}$, $\dot{C}H_3$ etc.

Free radicals are formed by the homolysis / ho-

molytic fission [equal breaking] of the covalent bond between two atoms. Homo = same/equal and lysis = breaking. Homolysis means equal breaking of a bond in such a way that both the bonded atoms get their shared electrons back. For example:

$$A \overset{\frown}{:} A \longrightarrow A^{\bullet} + A^{\bullet} \quad \text{[Free radicals]}$$

$$B \overset{\frown}{:} B \longrightarrow B^{\bullet} + B^{\bullet} \quad \text{[Free radicals]}$$

Homolysis results in the formation of free radicals which are the most reactive among chemical species.

EXAMPLE: When methane reacts with chlorine gas in the presence of sunlight, free radicals are formed and a chain reaction is set up.

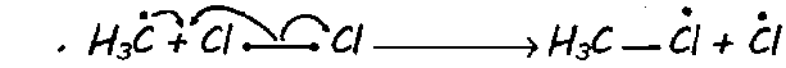
1. First chlorine molecule (Cl_2) breaks into free radicals:

$$Cl \overset{\frown}{:} Cl \xrightarrow{\text{Sunlight}} \dot{Cl} + \dot{Cl}$$

2. Then chlorine free radicals react with methane (CH_4) molecule and form methyl free radical.

$$H-\underset{H}{\overset{H}{\overset{|}{\underset{|}{C}}}}-H \overset{\frown}{:} \dot{Cl} \longrightarrow H_3\dot{C} + HCl$$

The ($\dot{C}H_3$) methyl free radical is very much reactive, further react with a chlorine molecule to form chloromethane (CH_3Cl) and chlorine free radical ($\dot{C}l$).



This reaction continuous till all the hydrogens of methane are replaced by chlorine free radicals.

Q11: What is molecule? Explain various types of molecules with the help of examples.
مالیکیول کی تعریف کریں۔ مالیکیول کی مختلف اقسام کی وضاحت کریں۔

Ans. **Molecule:** (Swat 2019)

Definition: "The smallest particle of matter which can exist free in nature is called a molecule." Molecule is formed by the chemical combination of atoms. A molecule may be composed of similar / like or unlike atoms. It shows all the properties of that particular substance.

Types of Molecules:

Depending upon the number and types of atoms, molecules are of the following types:

1. **Mono-Atomic Molecules:**

"A molecule made up of only one atom is called a mono-atomic molecule." For example, molecules of noble gases such as: Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr) and Xenon (Xe).

2. **Di-Atomic Molecules:**

"Molecules made up of two similar or two different atoms are called di-atomic molecules."

Examples are:

H_2, N_2, Cl_2, O_2, HCl, CO, NO.

a. **Homo-Atomic / Homo-Nuclear Di-Atomic Molecules:**

"Molecules made up of two similar atoms are

called homo-nuclear diatomic molecules."

Examples:

H_2, Cl_2, Br_2, O_2, N_2

b. Heteronuclear Di-Atomic Molecules:

"Molecules made up of two different atoms are called hetero-atomic / hetero-nuclear diatomic molecules."

Examples:

HF, HCl, CO, NO

3. Poly-Atomic Molecules: Poly = many,

"Molecules made up of more than two similar or different atoms are called polyatomic molecules."

Examples:

H_2O, CO_2, NH_3, CH_4, H_2SO_4, $C_{12}H_{22}O_{11}$, P_4, S_8, O_3 etc.

Polyatomic molecules can be homonuclear like O_3, P_4, S_8 and heteronuclear like CO_2, H_2SO_4. Polyatomic molecules containing 3-atoms are called tri-atomic molecules like CO_2, H_2O, SO_2 while those which contain 4-atoms are called tetra-atomic like P_4, SO_3, NH_3 etc.

4. Macro-Molecules: Macro = very large/big

"Molecules of high molecular masses, whose molecular masses are usually greater than 10,000amu are called macro-molecules."

Examples: Haemoglobin is made up of nearly 10,000 atoms and it is 68,000 times heavier than a hydrogen atom. Other examples are protein, carbohydrates etc.

Atomiciticity:

"The number of atoms present in a molecule is called its atomiticity."

Atomiticity of Cl_2 = 2

Atomiticity of NH_3 = 4

Atomiticity of $C_6H_{12}O_6$ = 24

Q12: What do you understand/mean by the term mole and Avogadro's number? Explain with suitable examples. مثالوں کی مدد سے مول اور ایواگاڈرو نمبر کی وضاحت کریں۔

Ans. **Mole:**

(Mardan, Peshawar, Kohat, Abbottabad 2019)

Mole is a Latin word which means a huge (الڈھیر) mass. Mole is a counting unit. Mole is the unit of amount of a substance. It is represented by "n".

As 2 similar things is equal to 1 pair

12 similar things is equal to 1 dozen

100 similar things is equal to 1 century

144 similar things is equal to 1 gross

1000 similar things is equal to 1 kilo

Similarly, "a group of 6.023×10^{23} similar things is called one mole."

Definition-2:

"Gram atomic masses, gram molecular masses and gram formula masses is also called mole."

We use different units in our daily life to represent different quantities of items. For example shoes are counted by pairs, eggs and bananas are counted in dozens and paper by ream.

Chemists also use a unit for counting atoms, ions and molecules. This counting unit is called mole. Mole unit is used to count/ measure the amount of substance.

Mole is also defined as "the amount/mass of a substance which contains Avogadro's number [6.023×10^{23}] of particles is called mole."

Atomic mass of C = 12 amu,
Expressed in grams = 12g = 1mole
Molecular mass of H_2O = 18amu,
Expressed in grams = 18g = 1mol
Molecular mass of H_2SO_4 = 98amu,
Expressed in grams = 98g = 1mol
Formula mass of NaCl = 58.5amu,
Expressed in grams = 58.5g = 1mol

Avogadro's Number: (Mardan 2019)

Definition: "The number of particles present in one mole of a substance is called Avogadro's number." It is represented by N_A. Its value is 6.023×10^{23}. This number was determined by an Italian scientist Amedo Avogadro that is why it is called Avogadro's number. For example:

1 mole of H = 6.023×10^{23} hydrogen atoms
1 mole of H_2 = 6.023×10^{23} hydrogen molecules
1 mole H_2O = 6.023×10^{23} water molecules
1 mole CO_2 = 6.023×10^{23} CO_2 molecules

Relationship between number of moles and Avogadro's number:

1.00 gram hydrogen = 1 mole = 6.023×10^{23} H-atoms

2·00 grams hydrogen(H_2) = 1mole = $6·023 \times 10^{23}$ H_2-molecules
12 grams carbon = 1mole = $6·023 \times 10^{23}$ C-atoms
18 grams water = 1 mole = $6·023 \times 10^{23}$ H_2O-molecules
58·5 grams NaCl = 1 mole = $6·023 \times 10^{23}$ NaCl f·units

SOCIETY, TECHNOLOGY & SCIENCE:

- If there were one mole of rice gains (چاول کے دانے) all the land area in the whole world would be covered with rice to a depth of about 75 meters·
- One mole of rice grains is more than all the grains that has been grown since the beginning of time·
- If a computer counts 10 million (ایک کروڑ) atoms per second, it will take 2-billion (دو ارب سال) years to count one mole of atoms·
- If one mole of marbles were spread over the surface of earth, the earth would be covered by a three miles thick layer of marble·

Q13: Define and explain gram atomic mass, gram molecular mass and gram formula mass·
گرام ایٹمی کمیت، گرام مالیکیولی کمیت اور گرام فارمولا کمیت کی تعریف اور وضاحت کریں۔

Ans· Gram Atomic Mass:

Definition: "When the relative atomic masses are expressed in grams then these are called gram atomic masses [mole]·"

Gram atomic mass of hydrogen = 1·008 grams
Gram atomic mass of oxygen = 16 grams
Gram atomic mass of chlorine = 35·5 grams
One gram atom of any element is the relative atomic mass of that element expressed [taken] in grams·
1 gram atom of hydrogen = 1·00g = 1 mole hydrogen
1 gram atom of oxygen = 16g = 1 mole oxygen
1 gram atom of carbon = 12g = 1 mole carbon
It is clear from the above examples that one gram atom of different elements have different masses·

Gram Molecular Mass:

Definition: "The molecular mass of a substance when expressed [taken] in grams it is called gram molecular mass or gram molecule of that substance·" It is also called mole·

Gram molecular mass of water (H_2O) = 18 grams
Gram molecular mass of carbondioxide (CO_2) = 44 grams
Gram molecular mass of sulphuric acid = 98 grams

Gram Formula Mass:

Definition: "The formula mass of an ionic compound when expressed [taken] in grams, it is called gram formula mass or gram formula·" It is also called mole·

Gram formula mass of NaCl = 58·5g (1-mole)
Gram formula mass of $CaCl_2$ = 111g (1-mole)
Gram formula mass of MgO = 40g (1-mole)

Q14: How mole calculations are carried out? Explain in detail.
کسی چیز کی مولوں کی تعداد کیسے معلوم کی جاتی ہے؟ مثالوں سے واضح کریں۔

Ans. Mole Calculations / Chemical Calculations:
(Mardan 2018)

In chemical calculations we can calculate:

1. Number of moles from the given mass
2. Number of particles from the given moles

Formulae used to find out the number of moles are given below:

$$\text{Number of moles (n)} = \frac{\text{Mass of substance (grams)}}{\text{Molar mass of the substance}}$$

$$\text{Number of moles (n)} = \frac{\text{Number of particles}}{\text{Avogadro's number}}$$

These chemical calculations are based on the conversion of mole into mass and mole into particles concept.

1. Mole-Mass Calculations:

In mole mass calculations one of the substances is given and the other will be calculated from the given data. In these calculations we can calculate the number of moles of the substance from the given mass. Similarly we can also calculate the mass of a substance from the given moles:

$$\text{Number of moles(n)} = \frac{\text{Mass of substance (grams)}}{\text{Molar mass of the substance}}$$

$$\text{Mass of substance} = \text{Number of moles(n)} \times \text{Molar mass}$$

EXAMPLE 1·3: Calculate the number of moles in 60 grams of CO_2:

Solution:

Given mass of CO_2 = 60g

Molar mass of CO_2 = 12 + 32 = 44g/mol

Wanted = Number of moles(n)

Using the formula:

$$n = \frac{Mass}{Molar\ mass}$$

$$n = \frac{60\,g}{44\,g/mol} = (1{\cdot}364\ moles)$$

PRACTICE PROBLEM 1·5:

How many moles are there in 90 grams of H_2O?

Solution:

Mass of water (H_2O) = 90 grams

Molar mass of H_2O = 2 + 16 = 18g/mol

Number of moles of H_2O = n = ?

Using the formula:

$$n = \frac{Mass}{Molar\ mass}$$

$$n = \frac{90\,g}{18\,g/mol} = (5\ moles)$$

2· Mole-Particles Calculations:

In this relationship we can calculate the number of moles from the given particles· Similarly if the number of moles are given [known] we can also calculate the number of particles [atoms, ions,

molecules, formula units]. We know that one mole of any substance contain Avogadro's number of particles (6.023×10^{23}). The following formula is used for calculating the number of moles with the help of the given particles:

$$\text{Number of moles } (n) = \frac{\text{Number of particles}}{\text{Avogadro's number}}$$

$$n = \frac{\text{Number of particles}}{N_A}$$

$$\text{Number of particles} = \text{Number of moles} \times N_A$$

$$= \text{No. of moles} \times 6.023 \times 10^{23}$$

EXAMPLE 1.4: How many moles of hydrogen are there in 8.9×10^{23} hydrogen atoms?

Solution:

Number of hydrogen atoms = 8.9×10^{23}

Number of hydrogen atoms per mole (N_A) = 6.023×10^{23}

Number of moles(n) = ?

Using the formula:

$$\text{Number of moles of hydrogen} = \frac{\text{Number of atoms}}{\text{Avogadro's number}}$$

$$= \frac{8.9 \times 10^{23}}{6.023 \times 10^{23}} = (1.48 \text{ moles})$$

Practice Problem 1.6:

(a) How many moles of CO_2 are there in 3.01×10^{23} molecules of CO_2?

(b) Calculate the number of molecules present in 5-moles of glucose, $C_6H_{12}O_6$.

Solution:

(a) Number of molecules of $CO_2 = 3{\cdot}01 \times 10^{23}$

Number of moles = n = ?

Formula used:

$$n = \frac{\text{Number of molecules}}{N_A}$$

$$n = \frac{3{\cdot}01 \times 10^{23}}{6{\cdot}023 \times 10^{23}} = 0{\cdot}4997 \cong (0{\cdot}5 \text{ moles})$$

(b) Number of moles = n = 5 moles

Number of molecules = ?

Formula used:

Number of molecules = $n \times N_A$

Number of molecules = $5 \times 6{\cdot}023 \times 10^{23}$

$= 30{\cdot}115 \times 10^{23}$

$= (3{\cdot}0115 \times 10^{24}$ molecules)

❀ غلطی ماننے اور گناہ چھوڑنے میں کبھی دیر مت کرو کیونکہ سفر جتنا طویل ہو جاتا ہے واپسی اُتنی ہی دُشوار ہو گی۔

❀ اپنے حصے کا کام کیے بغیر دُعا پر بھروسہ کرنا حماقت ہے۔

❀ رشتوں کی خوبصورتی ایک دوسرے کی بات کو برداشت کرنے میں ہے بے عیب انسان تلاش کرو گے تو اکیلے رہ جاؤ گے۔

❀ کسی کے چہرے پر مت جاؤ کیونکہ انسان ایک بند کتاب کی مانند ہے جس کے سرورق پر کچھ اور جبکہ اندرونی صفحات پر کچھ اور تحریر ہوتا ہے۔

❀ لوگوں کی زندگی میں اس نمک کی طرح رہو جو کھانے میں تو دِکھائی نہیں دیتا لیکن اگر نہ ہو تو اس کی کمی بہت محسوس ہوتی ہے۔

❀ موت کے لیے وقت مقرر ہے، عمر نہیں۔

Exercise

Choose the correct option:

1. Which one of the following group consist of elements?
   (a) Mercury, water, ammonia
   (b) Iodine, tin, iron✓
   (c) Copper, aluminum, methane
   (d) Coal, smoke, fog
2. Which one of the following can be broken down into simpler substances?
   (a) Ammonia✓ (b) Oxygen
   (c) Sulphur (d) Iron filling
3. Gram molecular mass of HNO_3 is:
   (a) 60 (b) 100
   (c) 63✓ (d) 98
4. Which of these molecules is not a compound?
   (a) N_2O **(b) N_2✓**
   (c) NO (d) NO_2
5. Which one of the following is equal to 2 moles of water?
   (a) 1.084×10^{25} molecules
   (b) 6.023×10^{23} molecules
   (c) 1.204×10^{24} molecules✓

$2 \times 6.023 \times 10^{23} \rightarrow 12.046 \times 10^{23} \rightarrow (1.2046 \times 10^{24})$

   (d) 1.806×10^{24} molecules
6. A compound contains:
   (a) Different kinds of atoms mixed together
   (b) The same kind of atoms mixed together

(c) Different kinds of atoms chemically combined✓

(d) Same kind of atoms chemically combined

7. Which one of the following is an example of triatomic molecule?

(a) CO_2✓ (b) O_2

(c) CH_4 (d) NH_3

8. Hydrogen gas is:

(a) Monoatomic gas

(b) A mixture of hydrogen atoms

(c) A diatomic gas with each molecule made up of two atoms✓

(d) A diatomic atom made up of two molecules

9. Which one of the following compound has both empirical and molecular formula identical?

(a) Benzene (C_6H_6)

(b) Hydrogen peroxide (H_2O_2)

(c) Water (H_2O)✓

(d) Glucose ($C_6H_{12}O_6$)

10. Which one of the following is homogeneous mixture?

(a) Smoke **(b) Air✓**

(c) Fog (d) Smog

Short Questions

Q1: How many elements are present in each of the following:

(a) Hf and HCl (b) Co and CO

(c) Si and SiO_2 (d) $POCl_2$ and $POCl_3$

Ans· Hf is the symbol of Hofnium element and is a single element while HCl is composed of two elements i·e· hydrogen and chlorine·

a) Co [cobalt] is a single element and CO [carbon dioxide] contains two elements·

b) Si [silicon] is a single element and SiO_2 contains two elements silicon and oxygen·

c) $POCl_2$ contains 3 elements and $POCl_3$ also contains 3 elements i·e· phosphorus, oxygen and chlorine·

Q2: Cm is the chemical symbol of curium, named after the famous scientist Madam Curie· Why was not the symbol "C, Cu and Cr" were used instead of Cm?

Ans· The elements carbon, cuprum [copper] and chromium were discovered before curium· The symbol "C" was assigned to carbon, "Cu" to copper and "Cr" to chromium· So when the element curium was discovered and prepared by Madam Curie, the symbol "Cm" was assigned / used for it instead of C, Cu, Cr in order to avoid ambiguity (ابہام)·

Q3: What is the atomic number of an element? How does it differ from the mass number?

Ans. Atomic Number: The number of proton present in the nucleus of an atom is called atomic number. It is represented by Z.

Mass Number: The sum of the number of proton and neutron present in the nucleus of an atom is called mass number. It is represented by A.

Differences between Atomic Number and Mass Number:

Atomic Number	Mass Number
1. It is the number of protons or electrons in an atom.	1. It is the sum of proton and neutron in the nucleus of an atom.
2. It is represented by Z.	2. It is represented by A.
3. Its value is lower than mass number.	3. Its value is higher than atomic number.
4. It is also called proton number.	4. It is also called nucleon number.
5. It is the identity/ characteristic of an element.	5. It is not the identity or characteristic of an element.
6. Modern periodic table is based on atomic number.	

Q4: Students often mix up the following elements. Give the name for each element.
(a) Mg and Mn (b) K and P

(c) Na and S (d) Cu and Co

Ans. The names of the elements are:

Mg: Magnesium	Mn: Manganese
K: Kalium [potassium]	P: Phosphorus
Na: Natrium [sodium]	S: Sulphur
Cu: Cuprum [copper]	Co: Cobalt

Q5: (a) Classify the following molecules as monoatomic, diatomic, triatomic and polyatomic molecules. H_2O, N_2, S_8, He, HCl, CO_2, Ar, H_2SO_4, $C_6H_{12}O_6$
(b) Classify the following as cation, anion, molecular ions, free radicals and molecules: C^+H_4, O^{-2}, $C^{\bullet}H_3$, C^+O, CO_2, $\bar{C}l$, Mg^{+2}, CO_3^{-2}, O_2, Na^+, $C_2H_5O^{-1}$, H_2O, Cl_2.

Ans.

(a) Monoatomic molecules: Ar, He
Diatomic molecules are: N_2, HCl
Triatomic molecules are: H_2O, CO_2
Polyatomic molecules are: S_8, H_2SO_4, $C_6H_{12}O_6$

(b) Cations: Mg^{+2}, Na^{+1}
Anions: O^{-2}, $\bar{C}l$
Molecular ions: $\overset{+}{C}H_4$, $\overset{+}{C}O$, CO_3^{-2}, $C_2H_5O^{-1}$
Free radicals: $\overset{\bullet}{C}H_3$
Molecules: CO_2, O_2, H_2O, Cl_2

Q6: Calculate the number of moles of butane (C_4H_{10}) in 151 grams of butane. Atomic masses: C=12, H = 1amu

Solution: Mass of butane = 151 grams

Molar mass of butane = C_4H_{10}

= (12x4) + (1x10) = 58g/mol

Number of moles of butane = n = ?

Formula used:

$$n = \frac{Mass}{Molar\ mass}$$

$$= \frac{151\ g}{58\ g\ /\ mol} = \boxed{2{\cdot}603\ moles}$$

Q7: What is the mass of 5-moles of ice? Atomic mass of H = 1amu, O = 16amu.

Solution:

Number of moles of ice ($H_2O_{(s)}$) = 5 moles

Molar mass of ice (H_2O)

= (2 x 1) + (1 x 16) = 18 g/mol

Mass of ice = ?

Formula used:

$$n = \frac{Mass}{Molar\ mass}$$

Re-arranging

Mass of ice = Number of moles of ice x Molar mass of ice

$$Mass\ of\ ice = \frac{5\ \cancel{moles} \times 18g}{\cancel{moles}} = \boxed{90g}$$

Q8: Calculate the number of molecules in 6·50 mole of CH_4.

Solution:

Number of moles of CH_4 = n = 6·50 moles

Avogadro's number = $N_A = 6{\cdot}023 \times 10^{23}$

Number of molecules = ?

Formula used:

$$\text{Number of moles of methane} = \frac{\text{No. of molecules of } CH_4}{\text{Avogadro's number}}$$

No. of molecules of CH_4 = No. of moles of methane x N_A

$= 5 \times 6.023 \times 10^{23}$

$= 30.115 \times 10^{23}$ molecules

$= (3.0115 \times 10^{24}$ molecules)

Q9: Calculate the average atomic mass of lithium from the following data:

Isotopes	Natural abundance %	Relative atomic mass (amu)
^6Li	7.50	6.0151
^7Li	92.50	7.0160

Solution:

$$\text{Average atomic mass} = \frac{(6.0151 \times 7.50) + (7.0160 \times 92.50)}{100}$$

$$= \frac{45.113 + 648.98}{100}$$

$$= \frac{694.093}{100} = \boxed{6.940}$$

Q10: Calculate the mass of 6.68×10^{23} molecules of PCl_3.

Solution:

Number of molecules of $PCl_3 = 6.68 \times 10^{23}$

Molar mass of $PCl_3 = (1 \times 31) + (3 \times 35.5)$

$= 31 + 106{\cdot}5 = (137{\cdot}5)$

$$\text{Number of moles} = (n) = \frac{\text{No. of molecules}}{N_A}$$

$$n = \frac{6{\cdot}68 \times 10^{23}}{6{\cdot}023 \times 10^{23}} = 1{\cdot}109^{23-23}$$

$= (1{\cdot}109 \text{ moles})$

$$\text{Mass of } PCl_3 = n \times \text{molar mass}$$

$= 1{\cdot}109 \text{mole} \times 137{\cdot}5 \text{g·mol}$

$= (152{\cdot}48 \text{ grams})$

Long Questions

Q1: State and explain with examples:
(a) Empirical formula of the compound
(b) Molecular formula of the compound

Ans: Please see question # 8

Q2: What do you understand by the term mole and Avogadro's number? Explain with suitable examples.

Ans: Please see question # 12

Q3: (a) Compare and contrast a mixture and a compound. Give examples of each of them.
(b) How will you classify molecules? Support your answer with at least two examples of each.

Ans: Please see question # 5 for part-a and see question # 11 for part-b.

Q4: (a) What is the molecular mass of a compound? How will you differentiate it from for-

mula mass?
(b) Calculate the molecular mass or formula mass, as the case may be of the following compounds in amu: (i) Benzene [C_6H_6] (ii) Ethane gas [C_2H_6] (iii) Aluminum chloride [$AlCl_3$] (iv) Iron oxide [Fe_2O_3]

Ans:

*(a) **Molecular Mass:** The sum of the relative atomic masses of all atoms present in a molecule is called molecular mass. Molecular mass means mass of a single molecule. Its unit is amu. For example;*

Molecular mass of H_2O
= (1x2) + (16x1) = 2 + 16 = 18 amu

Molecular mass of CO_2
= (12x1) + (16x2) = 12 + 32 = 44 amu

Differences between Molecular Mass and Formula Mass:

Molecular mass is different from formula mass because molecular mass is the sum of the relative atomic masses of all atoms present in a molecule while formula mass is the sum of the relative atomic masses of all atoms present in the formula unit.

Examples of Formula Masses:

Formula mass of NaCl = 23 + 35.5 = 58.5 amu

Formula mass of $CaCl_2$
= 40 + (35.5x2) = 40 + 71 = 111 amu

(b) (i) Benzene → C_6H_6 :

$(6 \times 12) + (6 \times 1) = 72 + 6 = 78$ amu

(ii) Ethane gas → C_2H_6:

$(2 \times 12) + (6 \times 1) = 24 + 6 = 30$ amu

(iii) Aluminum chloride [$AlCl_3$]:

$(1 \times 27) + (3 \times 35{\cdot}5)$

$= 27 + 106{\cdot}5 \Rightarrow 133{\cdot}5$ amu

(iv) Iron oxide → Fe_2O_3 : $(2 \times 56) + (3 \times 16)$

$\Rightarrow 112 + 48 \Rightarrow 160$ amu

Q5: (a) Find out the number of protons, electrons and neutrons in the following elements:

Ans:

	At·No·	Mass No·	Protons	Electrons	Neutrons
$_{11}Na^{23}$	11	23	11	11	12
$_{47}Ag^{107}$	47	107	47	47	60
$_{26}Fe^{56}$	26	56	26	26	30
$_{82}Pb^{207}$	82	207	82	82	125
$_{18}Ar^{40}$	18	40	18	18	22
$_{92}U^{238}$	92	238	92	92	146

(b) Complete the following table:

	Symbol	At· No·	Proton No·	Electron No·
a	K	-	-	-
b	-	8	-	-
c	-	-	15	15
d	-	20	-	-
e	Cl^-	-	-	-

The complete table is below:

	Symbol	At. No.	Proton No.	Electron No.
a	K	19	19	19
b	O	8	8	8
c	P	15	15	15
d	Ca	20	20	20
e	Cl	17	17	17

❑❑❑

CHAPTER

2 STRUCTURE OF ATOM

Introduction: *(Mardan 2019, Abbottabad 2019)*

The word atom is derived from the Greek word "άτομος" [atamos] which means uncut/indivisible.

The universe is made up of three things, matter, energy and space. Matter is composed of very small particles called atoms. This concept of matter was known to ancient (قدیم) philosophers like Democritus [400 BC] in Greece.

In the early 19th century in 1808, it was John Dalton, an English school teacher, who after a series of experiments concluded that all matter is composed of tiny [small] particles which are like solid balls and cannot be further divided. He called these indivisible particles as atoms. He presented his theory under the title "A new system of chemical philosophy".

Q1: Write down the main points of Dalton atomic theory.

Ans. **Main Points of Dalton Atomic Theory:** *(Kohat 2019)*

1. Matter is composed of very small particles

called atoms.

2. Atoms can neither be created nor destroyed.
3. Atoms of the same/particular element are identical (ایک جیسے) in size, shape and mass.
4. Atom is an indivisible (ناقابل تقسیم) particle.
5. Atoms of different elements are different in size, shape, mass and other properties.
6. Atoms combine with each other in small whole number ratio [H_2O, 2:1, NH_3, 1:3 etc] to form molecule.
7. All chemical reactions are due to combination or separation of atoms.

Changes in Dalton's Atomic Theory:

At the end of the 19th century, Dalton's theory was modified (ترمیم کی گئی). The changes in Dalton's theory mostly concerned the nature, composition and structure of atom.

1. According to modern research atom is divisible particle because atom is further composed of electrons, proton and neutrons.
2. Atoms of the same element can differ in terms of their atomic masses such as isotopes.

H	=	$_1H'$,	$_2H'$,	$_3H'$
Element		Protium	Deutrium	Tritium

3. The ratio between atoms in some organic compounds is not simple. For example: Vitamin-A, $C_{20}H_{30}O$, Vitamin B_{12}: $C_{63}H_{88}O_{14}N_{14}PCO$.

4. Atoms can be created, can be made artificially and can be converted to other atoms [transformation of atoms].

Q2: Write a detailed note on Rutherford's atomic model [Discovery of nucleus].

Ans. In 1911, Lord Rutherford a New Zealander scientist carried out an experiment in order to know the arrangement of electrons and protons in an atom.

Rutherford Experiment/ Discovery of Nucleus:

(Peshawar 2019, Bannu 2019)

Rutherford performed an experiment to determine the internal structure of the atom in 1911.

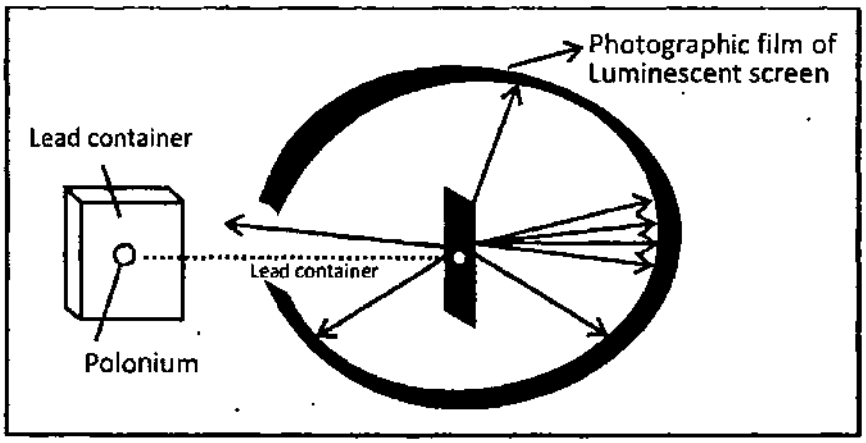
Rutherford bombarded a very thin Gold foil [0.00004cm thick] with alpha (α) particles. Alpha particles were obtained from a radioactive metal. A photographic plate was placed behind the foil, in order to observe the extent of scattering of α – particles. Instead of photographic plate zinc sulphide [ZnS] fluorescent screen can also be used. whenever an alpha particle struck the screen, a flash of light was produced on that point.

Observations:

He bombarded the gold foil with approximately

20000 alpha particles.

1. Most of the α – rays [19,990 rays] were passed straight through the gold foil un-deflected.
2. Some α – particles [8-particles] were deflected through smaller angle.
3. Very few α – particles [2 in 20,000] were bounced back at their original path.



Conclusion:

Rutherford concluded that an atom must contain a heavy and positive portion i.e. nucleus in the center of the atom. So α – particles passing near this portion were repelled because α – particles carry double positive (++) charge. He called this heavy central portion as nucleus which is from Latin word "nux" means nut (اخروٹ).

* If α – particles pass very closely to nucleus, they deflect through large angles. Similarly if they do not pass, close to nucleus, they either get deflected through

very small angles or do not deflect at all.

- On the basis of his conclusion, he proposed a new model of atom called planetary model similar to the solar system.

Main Points of Rutherford's Atomic Model:

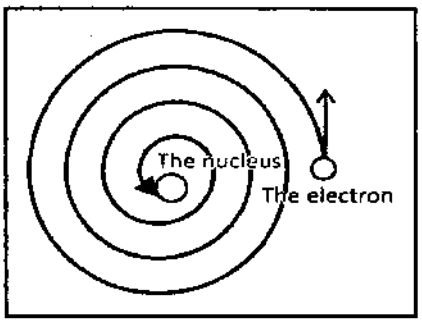
(BISE Malakand, Mardan 2018, Peshawar 2019)

1. Atom consists of positively charged central portion called nucleus. It contains protons and neutrons.
2. Electrons are revolving around the nucleus with very high speed.
3. The attractive force of the nucleus on electron provides centripetal force to the electron, due to which it moves in a circular path.
4. The size of the nucleus is very small as compared to the size of the atom. The diameter of the nucleus is about 10,000 times less than the diameter of the atom.
5. Major portion of the atom is empty (خالی).
6. Atom is neutral as the number of electrons is numerically equal to that of protons.
7. Nucleus is responsible for mass and energy of the atom.

Defects in Rutherford's Atomic Model:

1. Rutherford's atomic model is based on the laws of motion and gravitation which are applicable to neutral bodies and not to the charged bodies.

2. According to Maxwell theory, electrons being charged bodies, revolving around the nucleus should emit energy continuously and should fall into the nucleus.
3. If electrons radiate energy continuously, then continuous spectrum will be obtained but actually line spectrum is obtained.



4. It does not provide any explanation about the chemical properties of elements.
5. It does not explain the arrangement of electrons around the nucleus.
6. It does not give explanation about the structure of an atom.

Continuous Spectrum:

A spectrum in which there is no visible boundary between adjacent coloured lines is called a continuous spectrum.

Line Spectrum:

A spectrum in which there is visible boundary between adjacent coloured lines is called line spectrum.

Continuous Spectrum Line Spectrum

Q3: Explain Bohr atomic model. (Mardan 2017, Swat 2019)

Ans. In order to remove defects in Rutherford's atomic model, Neil Bohr in 1913 proposed a new model of hydrogen atom. Bohr was a Danish physicist. His model was based on Planks quantum theory of radiations. He assumed that the electron could not have any energy rather it was restricted to a particular set of energy values, which are better known as energy levels / shells / orbits. It means that the energy of electrons is fixed.

Main Points:

1. Electrons are revolving around the nucleus in fixed circular paths called orbits / shells. Each orbit is associated with a definite amount of energy. [Orbit has a fixed energy]
2. The energy of electrons in an orbit is directly proportional to its distance from the nucleus. The farther (دور) the electron from the nucleus, the higher will be the energy and vice versa (اور برعکس).
3. As long as electron revolves in its own orbit, it does not emit or absorb energy.
4. When an electron gains energy, it moves from lower energy level to higher energy level. [Energy of the orbit is fixed]
5. When an electron release energy it comes

back from higher energy level to lower energy level.

6. Energy is absorbed or released in the form of light radiations, whose frequency is directly proportional to the energy difference between the two orbits.

$$\Delta E \propto \upsilon$$

$$\Delta E = h\upsilon$$

$$E_2 - E_1 = h\upsilon$$

Where, E_2 = energy of higher orbit

E_1 = energy of lower orbit

h = Plank's constant [$h = 6{\cdot}626 \times 10^{-34}$ J·second]

υ = frequency of the emitted or absorbed radiation by electrons

ΔE = energy difference between the two levels

7. The angular momentum [mvr] of an electron is an integral multiple of $\frac{h}{2\pi}$.

$$mvr = \frac{nh}{2\pi}$$

Where, m = mass of electron

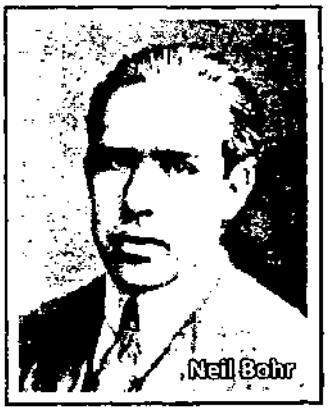
v = velocity of an electron

r = radius of the orbit in which electron is revolving

n = number of shell = 1,2,3...

h = Plank's constant

2π = Constant



The orbit defined by Bohr is also called a shell or energy level. These are represented by alphabets K, L, M, N, O, P, Q. The electrons present in K-shell (n = 1) have the least energy and it is nearest to the nucleus. The next shell is L (n = 2), which is higher in energy than K-shell and so on.

Q4: What is the importance of Bohr's model?

Ans. **Importance of Bohr's Model:**

1. It is used to calculate radius of an orbit.
2. It is used to calculate energy of the orbit.
3. It is used to calculate frequency of the emitted radiations.
4. Used to calculate energy difference between the two orbits.
5. Used to calculate wave number of the emitted or absorbed radiations.

Q5: Write down the properties of the fundamental particles of an atom.

Ans. According to the latest research an atom consist of more than 100 subatomic particles. Three subatomic particles electron, proton and neutron are very important to the chemists. These particles are called the fundamental particles of an element.

Electron:

1. It is negatively charged particle.
2. Its mass is equal to 0.00055amu.
3. Its mass is equal to 9.11×10^{-31}kg.

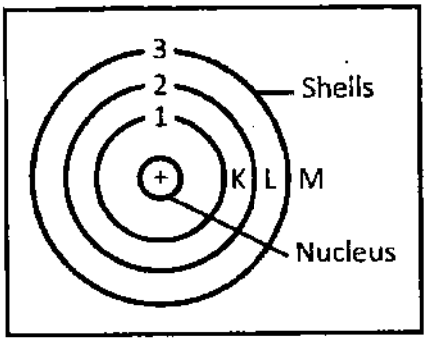
4. Charge on electron is equal to 1.6022×10^{-19}C.
5. Electrons are revolving around the nucleus.
6. It has unit negative charge (-1)
7. Electrons being light particles are revolving around the nucleus.

Proton:

1. It is positively charged particle.
2. Its mass is equal to 1.0073amu.
3. Its mass is equal to 1.67×10^{-27}kg.
4. Charge on proton is equal to 1.6022×10^{-19} coulomb.
5. It has unit positive charge (+1).
6. It is 1837 times heavier than an electron.
7. Protons are present in the nucleus.

Neutron:

1. Neutron is neutral/chargeless particle.
2. Its mass is equal to 1.0087amu.
3. Its mass is equal to 1.68×10^{-27}kg.



4. It is 1842 times heavier than an electron.
5. Neutrons are present in the nucleus.

Summary of the Sub-Atomic Particles					
Particle	Symbol	Unit charge	Charge (C)	Relative mass	Mass (Kg)
Electron	e^-	-1	1.6022×10^{-19}	0.00055 amu	9.11×10^{-31}
Proton	p^+	+1	1.6022×10^{-19}	0.0073 amu	1.67×10^{-27}
Neutron	n^o	0	0	0.0087amu	1.68×10^{-27}

Q6: Define electronic configuration. Explain the shell electronic configuration according to Bohr's $2n^2$ formula.

Ans. Electronic Configuration: (Peshawar 2019, Kohat 2019)

"The distribution of electrons in shells around the nucleus is called electronic configuration." Electrons are distributed according to the rule $2n^2$ [Bohr's formula]. Where "n" is the number of orbit. The orbits are numbered as 1,2,3,4,5,6,7,.....

These orbits are represented by K, L, M, N, O, P, Q, etc letters/ alphabets.

$2n^2$

Total number of electrons in 1st shell

$= 2 \times 1^2 = 2 \times 1 = 2$

Total number of electrons in 2nd shell

$= 2 \times 2^2 = 2 \times 4 = 8$

Total number of electrons in 3rd shell

$= 2 \times 3^2 = 2 \times 9 = 18$

Total number of electrons in 4th shell

$= 2 \times 4^2 = 2 \times 16 = 32$

Total number of electrons in 5^{th} shell
$= 2 \times 5^2 = 2 \times 25 = 50$

Total number of electrons in 6^{th} shell
$= 2 \times 6^2 = 2 \times 36 = 72$

EXAMPLES: Write down the electronic configuration of the 1st 15 elements of the periodic table:

$H^1[1] = K = 1$

$He^2 = K = 2$

$Li^3[3] = K = 2$, $L = 1$

$Be^4 = K = 2$, $L = 2$

$B^5[5] = K = 2$, $L = 3$

$C^6[6] = K = 2$, $L = 4$

$N[7] = K = 2$, $L = 5$

$O[8] = K = 2$, $L = 6$

$F[9] = K = 2$, $L = 7$

$Ne[10] = K = 2$, $L = 8$

$Na[11] = K = 2$, $L = 8$ $M = 1$

$Mg[12] = K = 2$, $L = 8$ $M = 2$

$Al[13] = K = 2$, $L = 8$ $M = 3$

$Si[14] = K = 2$, $L = 8$ $M = 4$

$P[15] = K = 2$, $L = 8$ $M = 5$

Q7: Explain the concept of sub-shells and orbitals.

Ans. **Shell / Orbit:**

Definition: "The circular area around the nucleus where probability [chances] of finding electrons is maximum is called a shell / orbit." Each shell is described by "n" value. "n" can have values

1,2,3,4,5,... As the value of "n" increases, shell number increases. The distance of electron from the nucleus and energy of electrons also increases.

Sub-Shell / Sub-Orbit:

Definition: "A group of orbitals of the same energy is called a sub-shell." Latest researchers shows that shells are composed of sub-shells and sub-shells are further composed of orbitals.

1st shell consists of only one sub-shell, known as s-sub-shell.

2nd shell consists of two sub-shells, known as s-sub-shell and p-sub-shell

3rd shell is composed of three subshells known as s-subshell, p-subshell and d-subshell.

4th shell contains four subshells known as s-subshell, p-subshell, d-subshell and f-subshell.

There are four subshells. Subshells are represented by s, p, d and f symbols. These are spectroscopic terms which stands for...

s = sharp p = principal
d = diffused f = fundamental

Maximum number of electrons which a subshell can accumulate:

s = 2, p = 6, d = 10, f = 14

Shell	Sub-shells	Representation
1	(i)	s
2	(ii)	s p

3	(iii)	s p d
4	(iv)	s p d f

n	Shell	Electrons	Sub-shells	Maximum es can accumulate
1	K	2	s	2
2	L	8	s, p	2 + 6
3	M	18	s, p, d	2 + 6 + 10
4	N	32	s, p, d, f	2 + 6 + 10 + 14
5	O	50	s, p, d, f, g	2 + 6 + 10 + 14 + 18
	.			

Orbital: (Kohat 2019)

Definition: "The three dimensional space around the nucleus where probability of finding electrons is maximum is called an orbital." An orbital can accumulate just 2-electrons. 1st s-subshell has only one orbital which is "s". It means that "s" is subshell as well as an orbital. p-subshell has three orbitals→ px, py, pz. d-subshell has five orbitals→ dxy, dyz, dxz, dx^2,y^2, dz^2. f-subshell has seven orbitals and has complicated names and shapes.

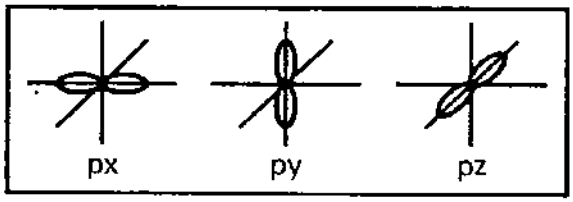
Shapes of Orbitals:

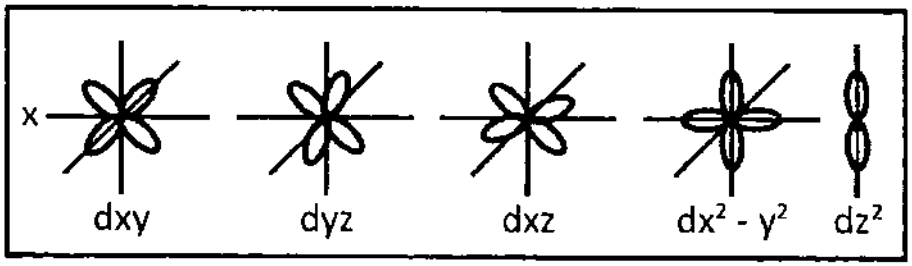
Shapes of s-Orbital: s-orbital has spherical shape.

It is denoted by a circle (○). It consists of one lobe only with no node.

Shape of p-Orbitals: p-orbitals are of three types, px, py and pz. These are along three axis. P-orbitals have dumb-bell shapes. Each p-orbital has two lobes, one on each side of the nucleus/ node.

Shapes of d-Orbital: d-orbitals have double dumb-bell shapes i.e. having four lobes.





Sub-shells Electronic Configuration:

Write down the electronic configuration of 1st eighteen elements of the periodic table.

Symbol	At.No.	K(1)	L(2-shell)		M(3-shell)		
		1s	2s	2p	3s	3p	3d
H	1	$1s^1$					
He	2	$1s^2$					
Li	3	$1s^2$	$2s^1$	-			
Be	4	$1s^2$	$2s^2$	-			
B	5	$1s^2$	$2s^2$	$2p^1$			
C	6	$1s^2$	$2s^2$	$2p^2$			

N	7	$1s^2$	$2s^2$	$2p^3$			
O	8	$1s^2$	$2s^2$	$2p^4$			
F	9	$1s^2$	$2s^2$	$2p^5$			
Ne	10	$1s^2$	$2s^2$	$2p^6$			
Na	11	$1s^2$	$2s^2$	$2p^6$	$3s^1$		
Mg	12	$1s^2$	$2s^2$	$2p^6$	$3s^2$		
Al	13	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^1$	
Si	14	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^2$	
P	15	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^3$	
S	16	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^4$	
Cl	17	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^5$	
Ar	18	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^6$	

$Ar = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6$

The increasing order of energy of sub-shells belonging to different shells is given below:

$1s < 2s < 2p < 3s < 3p < 4s < 3d$

The electrons are accommodated in the different energy levels by using AUFBAU principles.

AUFBAU Principles:

Aufbau is a German word which means building. "Electrons are put into various sub-shells in the order of increasing energy values". The order of increasing energy values is given below:

$1s < 2s < 2p < 3s < 3p < 4s < 4p < 5s < 4d < 5p...$

TEST YOURSELF

(i) Sodium has 11 protons and 12 neutrons. Write the electronic configuration of Na-atom.

Ans. As sodium atom has 11 protons so there

must be 11 electrons because atom is electrically neutral. Due to the presence of 11 protons its atomic number will be -11.

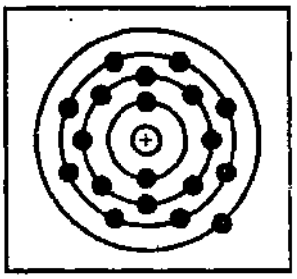
Na^{11}: $1s^2$, $2s^2$, $2p^6$, $3s^1$

(ii) Potassium has the electronic arrangement of 2,8,8,1

(a) What is its proton number

(b) Draw its electronic structure.

Ans. (a) From the electronic arrangement it is clear that potassium has total of 19 electrons (2+8+8+1=19) so there will be 19 protons also.



Ans (b): Electronic structure will be:

K = 2, L = 8, M = 8, N = 1

$1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $4s^1$

(iii) Write the electronic configuration of N, P, Ar.

Ans. N^7: $1s^2$, $2s^2$, $2p^3$

P^{15}: $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^3$

Ar^{18}: $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$

Q8: What are isotopes? Explain the isotopes of hydrogen, carbon, chlorine and uranium.
(BISE Malakand 2018)

Ans. Isotopes and Isotopy: Iso = same, tope = place
(BISE Mardan 2018, Abbottabad 2019, Bannu 2019)

Definition: "Atoms of the same element having the same atomic numbers but different mass numbers are called isotopes and this phenomenon

is called isotopy."

Soddy was the first scientist who discovered this phenomenon. As they occupy same place [one place] in periodic table so these are called isotopes. As isotopes have the same atomic numbers i.e. same number of electrons so they have the same chemical properties. The difference in mass of an atom in an element is due to the difference in number of neutrons. It means that isotopes possess different physical properties.

From the above discussion it is clear that isotopes can also be defined as "atoms of the same element having the same number of electrons and protons but different number of neutrons are called isotopes."

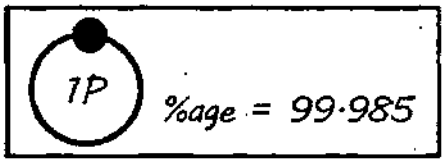
Isotopes can also be defined as "atoms of the same element having the same chemical properties but different physical properties are called isotopes."

Isotopes of Hydrogen: (BISE Mardan 2018)

The atomic number of hydrogen is 1. It has three isotopes, namely protium ($_1H^1$), deuterium ($_2D^1$) and tritium ($_3T^1$), with atomic masses 1, 2 and 3. The difference lies only in the number of neutrons. Protium has no neutron and its mass is only due to proton so it has got the name of protium. Protium is the most abundant isotope [99.985%] while deuterium is about 0.015% and tritium is very rare in nature.

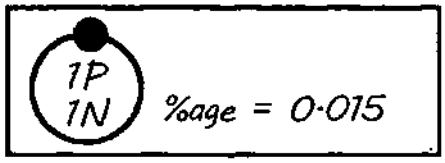
(i) Protium ($_1H^1$):

Atomic number = 1
Mass number = 1
Proton = 1
Electron = 1
Neutron = 0



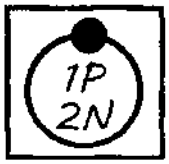
(ii) Deuterium ($_2D^1$):

Atomic number = 1
Mass number = 2
Proton = 1
Electron = 1
Neutron = 1



(iii) Tritium ($_3T^1$):

Atomic number = 1
Mass number = 3
Proton = 1
Electron = 1
Neutrons = 2



Due to the presence of same number of valence electrons, these isotopes have the same chemical properties. Their physical properties like melting point and boiling point are different. Differences in physical properties of oxides of protium and deuterium.

S·No	Property	H_2O	D_2O
1	Molecular mass	18·02	20·03
2	(amu)	1·000	1·105
3	Density at 0°C	0·00	3·82

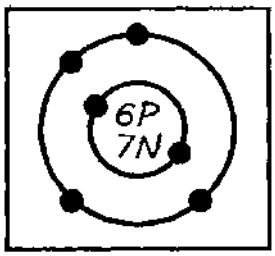
4	($g \cdot cm^{-3}$) Melting point (C°) Boiling point (C°)	100·00	101·42

Isotopes of Carbon:

The atomic number of carbon is 6· It is represent in IVA group and 2nd period· There are three isotopes of carbon in nature· C-12, C-13 and C-14·

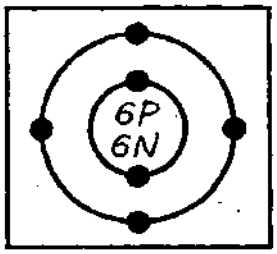
$_{12}C^{6}$:

Atomic number = 6
Mass number = 12
Protons = 6
Electrons = 6
Neutrons = 6



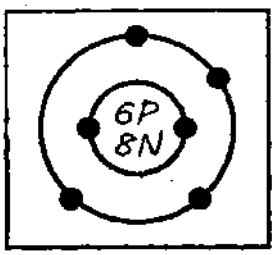
$_{13}C^{6}$:

Atomic number = 6
Mass number = 13
Protons = 6
Electrons = 6
Neutrons = 7



$_{14}C^{6}$:

Atomic number = 6
Mass number = 14
Protons = 6
Electrons = 6
Neutrons = 8



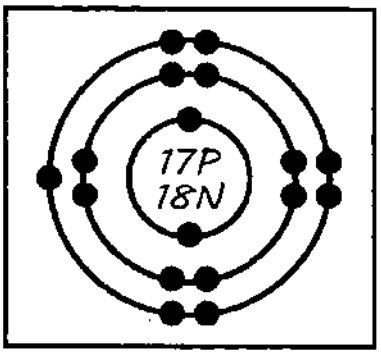
Isotopes of Chlorine:

The atomic number of chlorine is 17· It is present in VIIA group and 3rd period· There are

two isotopes of chlorine in nature Cl-35 and Cl-37. The natural abundance of Cl-35 is 75·53% and that of Cl-37 is 24·47%.

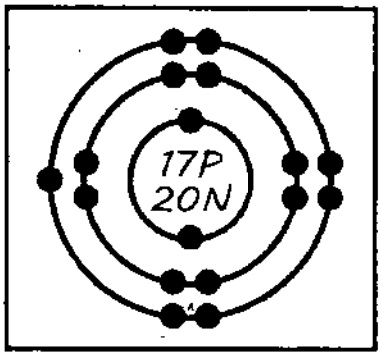
$_{35}Cl^{17}$:

Atomic number = 17
Mass number = 35
Protons = 17
Electrons = 17
Neutrons = 20
%age = 75·53



$_{37}Cl^{17}$:

Atomic number = 17
Mass number = 37
Protons = 17
Electrons = 17
Neutrons = 18
%age = 24·47

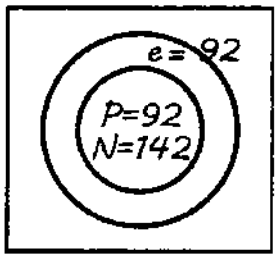


Isotopes of Uranium:

The atomic number of uranium is 92. There are three isotopes of uranium in nature, U-234, U-235 and U-238. Uranium-234 is about 0·05%, uranium-235 is about 0·75% while uranium-238 is the most abundant 99·245% in nature.

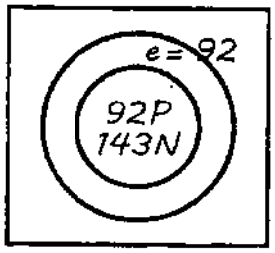
$_{234}U^{92}$:

Atomic number = 92
Mass number = 234
Protons = 92
Electrons = 92
Neutrons = 142



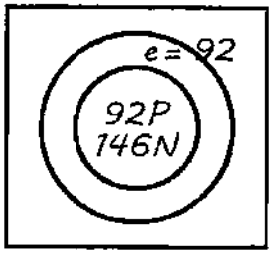
$_{235}U^{92}$:

Atomic number = 92
Mass number = 235
Protons = 92
Electrons = 92
Neutrons = 143



$_{238}U^{92}$:

Atomic number = 92
Mass number = 238
Protons = 92
Electrons = 92
Neutrons = 146



SOCIETY, TECHNOLOGY & SCIENCE

Dating: Estimation (اندازہ) of the age of the plant and animal remains by measuring the amount of radioactive decay products is called chemical dating or carbon dating. A more recent method involves the use of radioactive isotope C-14. This method is used in the study of deep sea sedimentation, dates of volcanic and glacier activity. The age of a uranium containing materials can be determined by measuring the percentage of lead formed as a result of disintegration (ٹوٹ پھوٹ) of uranium.

Q9: Write down the uses of isotopes.

Ans. **Uses of Isotopes:** (BISE Mardan, Swat 2019)
Isotopes are mainly used in chemical, agricultural (زراعتی) and medical research (طبی تحقیق) for diagnosing

(تشخیص) and treatment of diseases.

1. Iodine-131 [$_{53}I^{131}$] become concentrated (جمع ہونا) in the thyroid gland and is used as cure (علاج) for goiter (گلہڑ).
2. Iodine-123 [$_{53}I^{123}$] is used for brain imaging.
3. Deuterium heavy carbon [C-13], heavy nitrogen [N-15], heavy oxygen [O-18] and iodine-131 [$_{53}I^{131}$] are being used as tracer elements in biochemical and physio-chemical research to trace the path of the element to the defective or obstructed (رکاوٹی) part.
4. Radium irradiation and cobalt-60 [Co^{60}] are used in the treatment of cancer and for diagnosis of tumors (رسولی).
5. Sodium [Na-24] is used for the identification of blood circulation problems in patients.
6. Carbon-14 is used to trace the path of carbon in photosynthesis.
7. Americium-241 is used in smoke detectors. It is also used to determine that in which place oil wells should be drilled.
8. Californium-252 is used to measure the moisture content of soil in road construction and in building constructions. It is also used to inspect airplane luggage (سامان) for hidden explosive (خفیہ رکھا گیا خطرناک اشیاء).
9. Krypton-85 is used in electrical cloth washers to measure the dust and pollutants level.

Exercise

Choose the correct option:

1. The maximum number of electrons in 3^{rd} energy level is:
   (a) 10 **(b) 18✓**
   (c) 32 (d) 64
2. Mass of an atom is mostly due to its:
   (a) Nucleus✓ (b) Neutron
   (c) Electron (d) Proton
3. If Rutherford had used neutrons instead of α – particles in his scattering experiment the neutrons would:
   (a) Not deflected because they have no charge.✓
   (b) Have deflected more often.
   (c) Have been attracted to the nucleus easily.
   (d) Have given the same result.
4. Electron in its ground state does not:
   (a) Spin (b) Revolve
   (c) Radiate energy✓ (d) Reside in orbit
5. Which statement about ${}_6X^{12}$ and ${}_6Y^{14}$ is false?
   (a) They are isotopes
   (b) They are the same elements
   (c) They have the same number of electrons
   (d) They have the same number of neutrons✓
6. The neutron particle:
   (a) Has a mass equal to that of electrons
   (b) Has a mass approximately equal. to that

of proton✓

(c) Has charge equal to but opposite in that of an electron

(d) Has a positive charge

7. Isotopes of the same element have:

(a) The same number of protons✓

(b) The same number of neutrons

(c) Different number of electrons

(d) The same mass number

8. Which one is the lightest?

(a) An alpha particle

(b) A hydrogen atom

(c) An electron✓

(d) A proton

9. The nucleus of an atom has all of the following characteristics except that it:

(a) is positively charged (b) is very dense

(c) Contains nearly all of the atom's mass

(d) Contains nearly all of the atom's volume✓

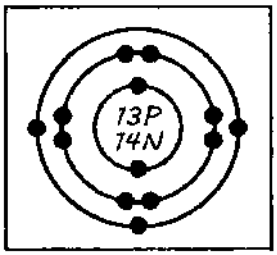
10. L-shell has sub sub-shells:

(a) s **(b) s and p✓**

(c) s, p and d (d) s, p, d and f

Short Questions

Q1: Aluminum is represented as $_{13}Al^{27}$. Draw the structure of aluminum. Write its electronic configuration.



Ans. The electronic structure of aluminum is:

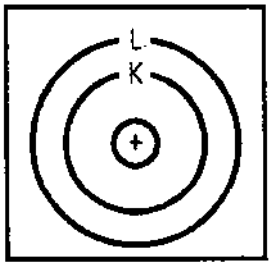
$[Al^{13}]$ = K = 2, L = 8, M = 3

The sub-shell electronic configuration of aluminum is:

Al^{13} = $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^1$

Q2: The energy of an electron in K and L shells is the same or different? Explain.

Ans. According to Bohr's atomic model, the energy of the electron in an orbit is directly proportional to its distance from the nucleus. It means that the farther (دور) the electron from the nucleus, the higher will be the energy and vice versa.

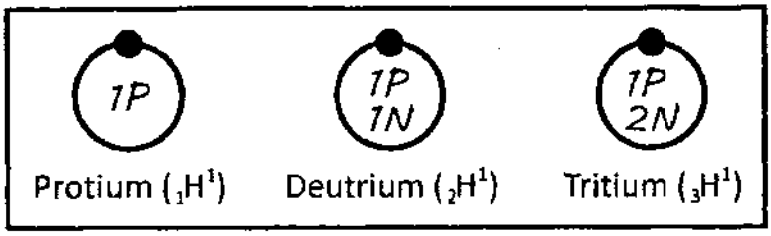


As we know that K-shell is close to the nucleus so electrons present in K-shell will have low energy. Similarly L-shell is far from the nucleus so electrons present in L-shell will have high energy. In nut shell the energy of an electron in K and L-shells will are different.

Q3: Draw the structures of hydrogen isotopes.

Ans. The structures of isotopes of hydrogen are

given below:



Q4: How many electrons are present in each of the following atoms? Assuming that each is a neutral atom, identify the element.
(a) $1s^2, 2s^2, 2p^6, 3s^1$
(b) $1s^2, 2s^2, 2p^6, 3s^2, 3p^5$
(c) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2$

Ans. In the above examples, the superscript represents the number of electrons in the sub-shells. Their summation will give the total number of electrons in that particular element.
As we know that the total number of electrons in atom is equal to its atomic number, so from the value of atomic number, its symbol can be easily find out in periodic table.

a) $1s^2, 2s^2, 2p^6, 3s^2, 3p^5$ (2+2+6+1 = 11)
Eleven is the atomic number of sodium (Na)

b) $1s^2, 2s^2, 2p^6, 3s^2, 3p^5$ (2+2+6+2+5 = 17)
17 is the atomic number of chlorine (Cl)

c) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2$ (2+2+6+2+6+2 = 20)
20 is the atomic number of calcium (Ca).

Q5: Why an atom is considered as neutral particle? Give reason(s).

Ans. Atom is considered as a neutral particle because the number of protons (positive charge) is equal to the total number of electrons (negative charge).

Q6: The mass of an atom is present in its nucleus? Can you explain?

Ans. We know that the two heavy sub-atomic particles protons and neutrons are present in the nucleus [Rutherford's experiment]. A proton is 1837 times heavier than an electron and neutron is 1842 times heavier than an electron. These two reasons give us proof that nearly total mass of an atom is present in its nucleus.

Q7: What is the reason that physical properties of isotopes are different but their chemical properties are the same?

Ans. We know that chemical properties depend upon the total number of electrons present in the valence shell of an atom. As isotopes have the same number of electrons so these have the same chemical properties. Isotopes have different number of neutrons so these have different physical properties (different masses).

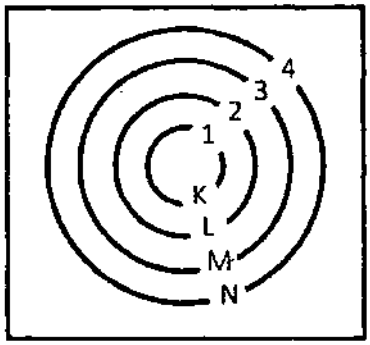
Q8: Draw the structure of carbon isotopes. Then write down the number of proton, neu-

tron and electrons.

Ans. Please see question # 8.

Q9: How many electrons could be contained in the K, L, M and N-shells?

Ans. Maximum number of electrons in an orbit can be find out by $2n^2$ formula. Shells are represented by numbers and letters i.e. 1, 2, 3, 4,
K, L, M, N



Number of electrons in K-shell: 2×1^2

Number of electrons in L(2)-shell: $2 \times 2^2 = 8$

Number of electrons in M(3)-shell: $2 \times 3^2 = 18$

Number of electrons in N(4)-shell: $2 \times 4^2 = 32$

Q10: Write detailed electronic configuration of Li-3, C-6 and Mg-12.

Ans. The electronic configuration of Li, C, Mg is given below:

$Li^3 = 1s^2, 2s^1$ OR [Li^3 = K = 2, L = 1]

$C^6 = 1s^2, 2s^2, 2p^2$ OR [C^6 = K = 2, L = 4]

$Mg^{12} = 1s^2, 2s^2, 2p^6, 3s^2$

OR [K = 2, L = 8, M = 2]

Q11: Write the symbol for an isotope.
(a) Containing one proton and two neutrons
(b) For which the atomic number is one and there is one neutron?

(c) For which the atomic number is one and the mass number is also one?

Ans.

(a) ${}_3H^1$ or ${}_3T^1$
(b) ${}_2H^1$ or ${}_2D^1$
(c) ${}_1H^1$

Long Questions

Q1: Why Dalton's atomic theory is considered as a base for modern atomic concept?

Ans: Dalton's atomic theory provides a base for modern atomic concept. For the first time he explains the composition of matter and said that matter is composed of small indivisible particles called atoms. So he gives the concept of atom as a basic unit of matter. Later on scientists worked on atom and proved experimentally that atom is further composed of two parts (nucleus and extra nuclear part/shells) [Rutherford's experiment]. According to latest researches atom is further composed of more than hundred sub-atomic particles. Modern scientists also worked on that it is further composed of sub-shells and orbitals.

From the above discussion it is clear that it was John Dalton who provides a base for modern atomic concept, as he presented his theory about the existence of atom.

Q2: Summarize Rutherford's model of an atom and explain how he developed this model based on the result of his famous gold foil experiment?

Ans: Lord Rutherford a New Zealander scientist did experiment to explain the structure of an atom. He bombarded a very thin gold foil with α – particles. He observed that most of the α – particles were passed straight through the gold foil undeflected from this he concluded. That most of the space of atom is empty.

Few rays were deflected at large angle and very few were bounced back on the original path. From this he concluded that atom has a central massive positive portion which caused the deflection and bouncing backing of the α – particles. Remember that α – particles carry positive charge. He called this central massive and positively charged portion as nux [Latin] "nucleus". So he discovered nucleus. He also concluded from his experiment that nearly total mass of the atom is concentrated in the nucleus. It is because only a heavy portion can bounce back the α – particles.

Q3: State the postulates [points] which Bohr suggested to overcome the shortcomings of the Rutherford's atomic model?

Ans: In order to remove defects in Rutherford's

atomic model Bohr suggested the following points:

1. Electrons are revolving in fixed circular paths called orbits.
2. When an electron revolves in its own orbit, it does not emit or absorb energy, it means that energy of an orbit is fixed.
3. Electron will leave its own orbit when it gain or lose energy.
4. Positively charged nucleus provide centripetal force to electrons, which compel (مجبور کرنا) them to move in circular path.

Q4: Complete the following table for neutral atoms of specific isotopes.

	Isotopic Symbol	At.No.	Mass No	No. of Protons	No. of Electrons	No. of Neutrons
a	$_{54}Xe^{131}$	-	-	-	-	-
b	-	27	59	-	-	-
c	-	-	144	-	-	84
d	-	22	-	-	-	26
e	-	-	-	-	72	106
f	-	-	128	52	-	-
g	-	-	-	18	-	22

	Isotopic Symbol	At·No·	Mass·No	No· of Protons	No·of Electrons	No·of Neutrons
a	$_{54}Xe^{131}$	54	131	54	54	77
b	$_{27}Co^{59}$	27	59	27	27	32
c	$_{60}Nd^{144}$	60	144	60	60	84
d	$_{22}Ti^{48}$	22	48	22	22	26
e	$_{72}Hf^{178}$	72	178	72	72	106
f	$_{52}Te^{128}$	52	128	52	52	76
g	$_{18}Ar^{40}$	18	40	18	18	22

Q5: Define energy level and sub-energy level·

Ans: Energy Level / Shell / Orbit:

"The circular region around the nucleus where chances of finding electron is maximum is called energy level·"

Sub-Energy Level /Sub-Orbit/Sub-Shell:

"A group of orbitals of the same energy is called a sub-energy level·" For example:

The division of shell is called sub-shell·

$$P \longrightarrow \underbrace{Px,\ Py,\ Pz}$$

Subshell — Orbitals of the same energy

Q6: Explain the distribution of electrons in various energy levels and sub-energy levels for 1st four elements of periodic table·

Ans: Electronic distribution of first four elements of periodic table is given below:

H-1	K = 1	$1s^1$
He-2	K = 2	$1s^2$

Li-3 K = 2, L =1 $1s^2, 2s^1$

Be-4 K = 2, L = 2 $1s^2, 2s^2$

❑❑❑

"Good relations are just like water, no colour, no shape, no place, no taste but still very very important for life."

- انسان چہرہ تو صاف رکھتا ہے جس پر لوگوں کی نظر ہوتی ہے مگر دِل کو صاف نہیں رکھتا جس پر اللہ کی نظر ہوتی ہے۔
- جب گناہ کے کاموں میں دِل لگنا شروع ہو جائے تو یہ اس بات کی دلیل ہے کہ تمہارا ربّ تم سے ناراض ہے۔
- پُر سکون نیند کا تعلق خوبصورت پُر آسائش کمرے اور بستر سے نہیں بلکہ پُر سکون روح اور ضمیر سے ہے۔
- بڑا انسان وہ ہوتا ہے جس کے سامنے کسی کو چھوٹا پن محسوس نہ ہو۔
- کانٹوں سے بھری شاخ کو ایک پھول خوبصورت بنا دیتا ہے، اسی طرح غریب سے غریب گھر کو نیک سیرت عورت جنت بنا دیتی ہے۔
- ہو سکتا ہے آپ کو کسی کی خوبصورتی سے پیار ہو جائے لیکن یہ یاد رہے زندگیاں کردار و اعمال کے ساتھ گزاری جاتی ہیں، خوبصورتی کے ساتھ نہیں۔
- داناؤں میں اعلیٰ درجہ کی دانائی تقویٰ، کمزوریوں میں سب سے بڑی کمزوری بداخلاقی اور بد عملی ہے۔
- دو بھوکے کبھی سیر نہیں ہوتے ایک علم کا بھوکا، دوسرا مال کا بھوکا۔
- کثرتِ گناہ سے دِل کی جس خراب ہو جاتی ہے پھر گناہ کی پریشانی اور ظلمت کا احساس بھی نہیں ہوتا۔

CHAPTER 3

PERIODIC TABLE OF ELEMENTS & PERIODICITY OF PROPERTIES

Introduction:

In the year 1800, only thirty four [34] elements were known. By the year 1870 this number increased to almost double and in the year 1974, the number of elements was 105. Recently 118 elements are known. Out of 118 elements 92 are natural and the remaining have been made artificially.

When the number of elements was limited so it was easy for chemists to study these elements individually. But as the time passed, the number of elements increased, so it became difficult for the chemists to study each element individually. A need was felt that the elements must be properly arranged so that they could be easily studied. By arranging elements one can get maximum informations with minimum efforts. A number of attempts were made from time to time to arrange the elements with similar properties into groups.

Classification:

"The arrangement of similar elements into one group and to separate them from different ele-

ments is called classification."

1. Al-Razi Classification:

Al-Razi classified the then known elements into metals and non-metals. This classification was failed because there were some elements which possess both the properties of metals and non-metals. These elements are called metalloids.

2. Dobereiner's Triads:

In 1817, J.W. Dobereiner a German physicist arranged chemically similar elements in groups of three on the basis of their atomic masses. He called these groups as triads. In a triad, the average of the atomic masses of the 1st and 3rd elements is approximately equal to the atomic mass of the middle element.

(i) Li = 7

Na = 23 = 23 $\quad \frac{7 + 39}{2} = \frac{46}{2} = 23$

K = 39

(ii) Ca = 40

Sr = 88 ≅ 88.5 $\quad \frac{40 + 137}{2} = 88.5$

Ba = 137

(iii) S = 32

Se = 79 ≅ 80 $\quad \frac{32 + 128}{2} = 80$

(iv) Cl = 35.5

Br = 80 ≅ 81.5 $\quad \frac{35.5 + 127}{2} = 81.5$

I = 127

This classification was failed because all the elements could not be classified in this way.

3. **Newland Classification:**

In 1864 an English chemist J. Newlands arranged the elements in order of their increasing atomic masses. He divided the elements into groups of seven elements and found that every 8th element had the properties similar to the 1st element of the preceding series. He called these groups as octaves. For example in the table given below lithium resemble sodium and so on.

Li^{7}	Be^{9}	B^{10}	C^{12}	N^{14}	O^{16}	F^{19}
Na^{23}	Mg^{24}	Al^{27}	Si^{28}	P^{31}	S^{32}	$Cl^{35.5}$

He could not properly classified all the elements in the same manner, so the law of octaves failed to classify all the elements.

4. **Mendeleev and Lother Meyer Classification:**

In 1869 two chemists, Lother Meyer in Germany and Dmitri Mendeleev in Russia at about the same time independently developed very similar arrangement of elements. They found that while arranging the elements in the order of their increasing atomic weight, certain physical and chemical properties are repeated at regular intervals.

Loter Meyer plotted atomic volumes. [densities] of the elements against their atomic masses and found that similar elements occupied similar posi-

tions in the graph.

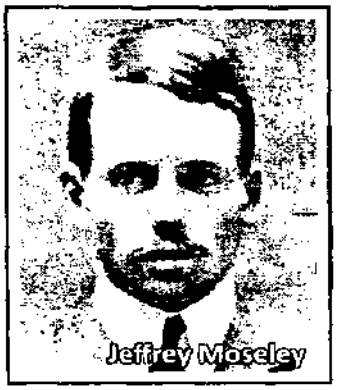
Dmitri Mendeleev arranged the elements in the form of table. He arranged 65 elements into periods and groups. In this table he left vacant spaces for the elements which were not discovered at that time and be placed in these vacant spaces. On the basis of this table, he predicted the properties of certain elements very accurately that were yet to be discovered.

Mendeleev classification was based on atomic mass. However with the discovery of atomic structure, it became clear that elements varied regularly with atomic number and not with atomic mass. Mendeleev laid down a base for the arrangement of elements. Due to his, this great contribution an element in periodic table is named after his name [Mendelevium – Md having atomic number 101].

Q1: Explain modern periodic table in detail.

Ans. The modern periodic table was put forward by Henry Gwyn Jeffreys Moseley. In 1913 an English physicist Moseley classified the elements in the order of their increasing atomic numbers. He found that atomic number is the fundamental property of an element. This English physicist presented modern periodic law.

Modern Periodic Law:



Definition: "Physical and chemical properties of elements are periodic functions of their atomic numbers." Modern periodic table is designed on the basis of this law. At present, the elements are arranged in order of their increasing atomic numbers. In which elements having similar properties and similar valence shell electronic configuration are repeated at regular intervals.

Periodic table is composed of eight vertical columns known as groups / families and seven horizontal rows known as periods.

Periodic Table:

"A table obtained by the arrangement of elements into groups and periods is called periodic table."

Features of Modern Periodic Table:

The essential features of modern periodic table are given below:

a. Periods and groups
b. Blocks in periodic table
c. Position of metals, non-metals and metalloids

a. Periods:

"The horizontal rows of elements from left to right in periodic table are called periods." There are seven periods in periodic table.

First Period: It is called the shortest period. It contains two elements, hydrogen and helium. Both are gases and are s-block elements.

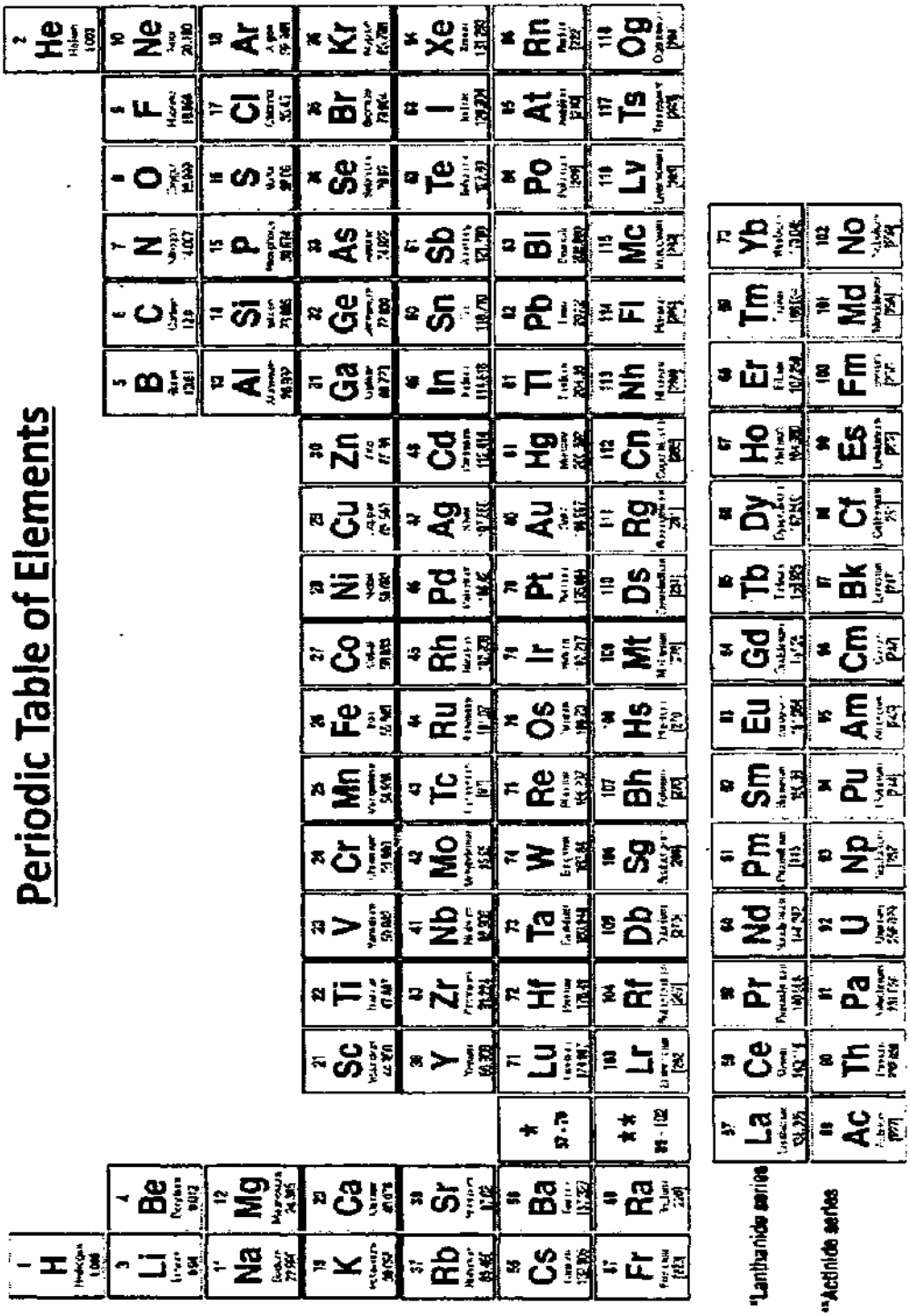
Second Period: It is called short period. It contains eight elements. All the eight elements are sub-group-A element, which are called normal [representative] elements.

Third Period: It is also called the short period. It contains eight representative elements.

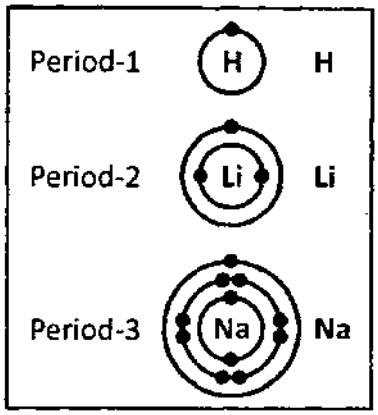
Fourth Period: It is called the long period. It contains eighteen elements. It contains 8 representative elements and 10 transition elements.

Fifth Period: It is also called the long period. It contains 18 elements. 8 elements are normal and the remaining 10 are transitions.

Sixth Period: It is the longest period. It contains 32 elements. It contains 8 normal elements, 10 transition elements and 14 rare earth elements, the lanthanides.


Periodic Table of Elements
*Lanthanide series
**Actinide series

7th Period: It is still incomplete. It contains two representative elements, 10 transition elements and 14 actinides.



NOTE: All the elements in the same period have the same number of shells. In the 1st period the number of shell is one, in the 2nd period all elements have two shells and so on. It means in a particular period, the number of shells remains the same.

Groups:

"Vertical columns of elements from top to bottom are called groups."

The periodic table is arranged in such a manner that the elements in the same group have the same number of electrons, in the outermost shells of their atoms. It means that they have the same valence electrons. Due to similarity in the number of valence electrons. The elements show resemblance in their chemical properties in the same group. Groups are of two types. Sub-group-A and sub-group-B.

- Elements of sub-group-A are called normal or representative elements.
- Elements of sub-group-B are called transition elements.
- There are total 18 groups in periodic table.

8 groups of normal elements and 10 groups of transition elements.

IA-Group:

Elements of this group [except-H] are called alkali metals. It is because when these elements are added to water, they reacts with water and form alkalies. It contains elements [Li, Na, K, Rb, Cs, Fr]. Elements of IA-group have one electron each in their last shells and they show similar chemical properties. These are very reactive, electropositive and metallic in nature.

IIA-Group:

Elements of IIA-group are called alkaline earth metals. They have two electrons each in their valence shells. These are less electropositive than alkali metals. This group contains the elements, beryllium, magnesium, calcium, strontium and radium.

IIIA-Group:

It is called Boron family. It contains the elements Boron, Aluminum, Galium, Indium, Thalium. These elements have four electrons in their last shells.

IVA-Group:

It is called Carbon family. It includes elements Carbon, Silicon, Germanium, Stannum and Plumbum. They have four electrons in their last shells.

VA-Group:

It is called Nitrogen family. It contains elements

Nitrogen, Phosphorus, Arsenic, Stabium and Bismuth. They have five electrons in their valence shells.

VIA-Group:

It is called Oxygen family. It contains elements, Oxygen, Sulphur, Selenium, Tellurium and Polonium. They have six electrons in their valence shells.

VIIA-Group:

Elements of this group are called halogens. Halogen means salt former. It contains elements Fluorine, Chlorine, Bromine and Iodine. They have seven electrons in their last shells. These are very electronegative. They show non-metallic characters.

VIIIA-Group:

Elements of this group are called noble gases, rare gases or inert gases. This is also called zero group. It contains the elements Helium, Neon, Argon, Krypton and Xenon. Helium contains two electrons in its valence shell while the other have eight electrons in their last shells.

Periodic Table in Four Blocks:

Elements in which the last electrons enter into s-subshell during electronic configuration are called s-block elements. IA group and IIA group elements are called s-block.

p-Block Elements:

Elements in which the last electrons enter into

p-subshell are called p-block elements. IIIA, IVA, VA, VIA, VIIA, VIIIA [except helium] comes in this category.

d-Block Elements:

Elements in which the last electrons enter into d-subshell are caleld d-block elements. These elements are also called transition elements. These include IB to VIIIB groups.

F-Block Elements:

Elements in which the last electrons enter into f-subshell are called f-block elements. These are also transition elements. Lanthanide and actinide series came in this category.

NOTE: s and p-block elements are called normal / representative elements d and f-block elements are called transition elements.\

Position of Metals, Non-Metals and Metalloids:

In periodic table metallic elements lie to the left and bottom of the periodic table. Non-metallic elements lie to the right and top of the periodic table. Metalloids are on the boarder line.

SCIENTIFIC INFORMATIONS

- The only letter that does not appear on the periodic table is J.
- The rarest (سب سے قلیل) naturally occurring element in the earth's crest is Astatine. The total crust appears to contain about 28 gram of this element.

Representative Elements:

(Mardan, Abbottabad 2019

All s-block and p-block elements are called representative elements.

Transition Elements:

Those elements which show variable oxidation states are called transition elements. All "d" and f-block elements are called transition elements.

Lanthanide Series:

Lanthanides are those elements which come after lanthanum in 6th period. Lanthanide series contain 14 elements which ranges from cerium (Ce-58) lutetium (Lu-71). These are placed at the bottom of the periodic table due to differences in their properties. These 14 elements are also called rare earth elements.

Actinides and Actinide Series:

Actinides are those elements which come after Actinium in the 7th period. A 14 member series starting from Actinium and ends at Lawrencium is called actinide series. This series ranges from thorium (Th-90) upto Lawrencium (Lr-103). These elements are placed below the actinides in the periodic table at the bottom.

PRACTICE PROBLEM 3.1:

- **Which is the first element of the second period in periodic table?**

- Which one is the last element of the second period of the periodic table?
- How many elements are in that period?

Ans· • Li • Ne • 8 elements

EXAMPLE 3·1: Use periodic table to identify the following:

1· 5th element of 1st transition series
2· Element of the 4th period that is also in VB group
3· The last lanthanide
4· The 7th transition element
5· The 2nd actinide metal
6· The 1st element of VIIIB group
7· The 3rd halogen
8· The 1st alkaline earth metal
9· The 1st coinage metal (سکہ بنانے والے عناصر) Cu, Ag, Au

Solution:

1· Mn 2· V 3· Lu 4· Co 5· Pa
6· Fe 7· Br 8· Be 9· Cu

PRACTICE PROBLEM 3·2:
Identify the 2nd noble gas·
Solution: Neon (Ne)

SCIENTIFIC INFORMATIONS

Hydrogen is the lightest, most abundant (عام) and explosive (دھماکہ خیز) gas on earth· Fluorine is the most reactive and most electronegative of

the elements, making elemental fluorine a dangerously powerful oxidant. This leads to direct reactions between fluorine and most elements, including noble gases krypton, xenon and radon. There are total 17 gases which can be found in atmosphere on earth. Only oxygen and nitrogen are found in large concentrations; 20.947% and 78.084% respectively. Oxygen concentrations below 16% are considered unsafe for humans.

- Group number indicates the number of electrons in the outermost shell of an atom.
- Period number indicates the number of shells in an atom.

TEST YOURSELF

- To which group does the element "K" belong? [IA]
- To which period does the element "arsenic" belong? [4]
- To which group does the element titanium belong? [IVB]
- State whether the following elements are metals or non-metals.
  Cesium, boron, selenium, phosphorus, astatine, osmium
  (Metal) (N-metal) (N-metal) (N-metal) (N-metal) (Metal)
- How many shells and valence electrons, the

element calcium will have? [4-shells and 2-valence electrons]

- Element "X" is located in period-3, group-II of the periodic table, deduce its electronic configuration.

Q2: Define periodic properties and periodicity of properties. Name some of the periodic properties.

Ans. Periodic Properties: (BISE Malakand 2018)

Definition: "Properties of elements which changes with change in period are called periodic properties." The properties which repeat again and again across the period and down the group are called periodic properties.

Periodicity of Properties:

Definition: "The repetition of a property after a regular interval is called periodicity of properties." (OR)

Definition: "The process / pattern by which there is repetition of properties in all the groups and the periods after a certain interval, are the periodicity of properties."

Periodicity:

Definition: "A pattern of repeating properties at regular interval is called periodicity."

Examples: Atomic size, atomic radius, ionization energy, electron affinity etc.

Q3: Explain atomic size, atomic radius, covalent radius. What is the periodicity of atomic radius?

Ans. 1. **Atomic Size:**

(Malakand 2018, Abbottabad 2019)

Measurement of accurate size of an atom is very difficult, it is because:

1. Atom is invisible
2. Atom cannot exist in free state.
3. The same atom may have different sizes in different combinations and different situations.
4. The size of an atom is not rigidly fixed but it varies when combined with different atoms.

The atomic sizes are usually expressed in terms of atomic radii and covalent radii.

Atomic Radius:

Definition: "The distance between the nucleus and valence shell of an atom is called atomic radius." The atomic radius is represented by "r". Atomic radius is directly proportional to the number of shells.

Units:

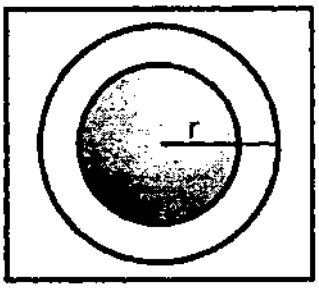
Various units used for the measurement of atomic radii are angstrom (A°).

$1A^{\circ} = 10^{-8} cm = 10^{-10} m$

Micrometer (μm) = $10^{-6} m$

Nanometer =(nm) = $10^{-9} m$

Picometer (pm) = $10^{-12} m$



Trends / Periodicity of Atomic Radius:

Atomic radius / size increases from top to bottom [down the group]. It is because the number of shells increases from top to bottom.

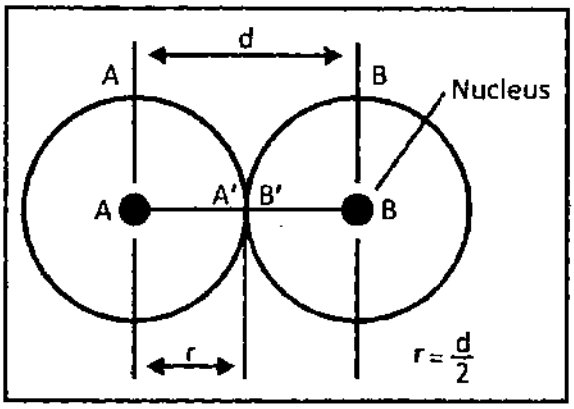
Atomic radius / size decreases from left to right along the period. It is because, atomic number increases from left to right, one proton is added to the nucleus continuously along the period. Therefore, the attraction of the nucleus for the valence electrons increases which pulls them nearer to the nucleus. Thus the atomic radius decreases.

Atomic Radii in Angstrom (Å) of the Representative Elements:

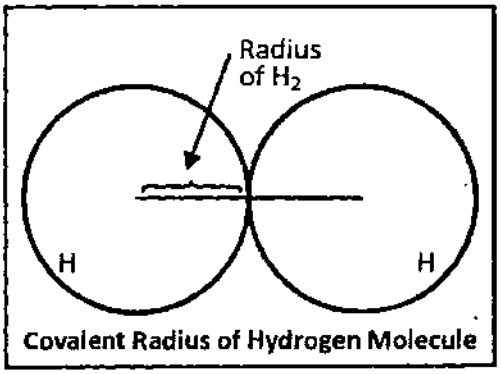
H 0·37							He 0·49
Li 1·23	Be 0·89	B 0·80	C 0·77	N 0·74	O 0·74	F 0·72	Ne 0·51
Na 1·35	Mg 1·36	Al 1·25	Si 1·17	P 1·10	S 1·04	Cl 0·99	Ar 0·88
K 2·03	Ca 1·74	Ga 1·25	Ge 1·22	As 1·21	Se 1·17	Br 1·14	Kr 1·03
Rb 2·16	Sr 1·91	In 1·59	Sn 1·41	Sb 1·41	Te 1·37	I 1·53	Xe 1·24
Cs 2·35	Ba 1·98	Tl 1·55	Pb 1·54	Bi 1·52	Po 1·53	At 1·63	Rn 1·34

2. Covalent Radii: (Mdn 2018, Bannu 2019)

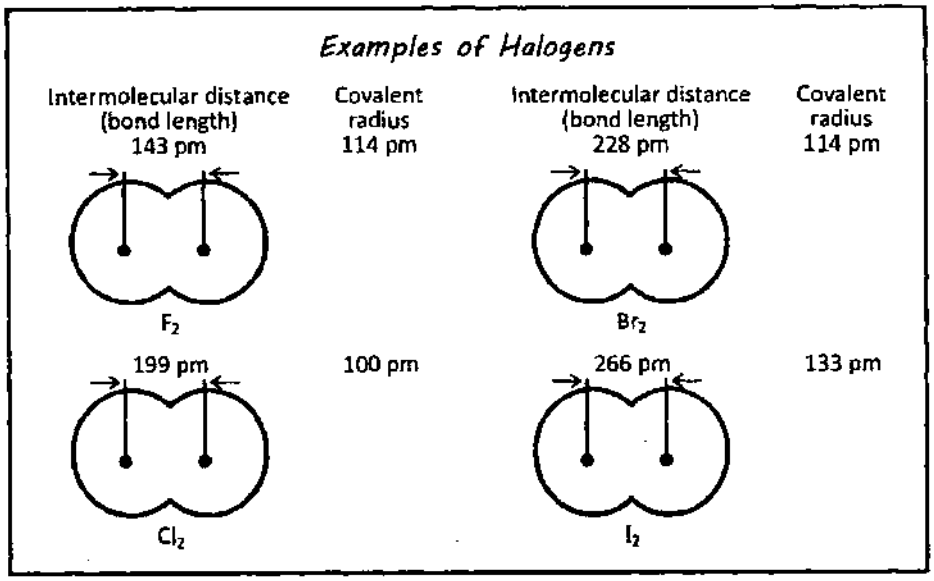
Definition: "The one half of the distance between the nuclei of two similar atoms of the same molecule containing a single covalent bond is called covalent radius." (OR)



"Half of the distance between the nuclei of two covalently bonded similar atoms is called covalent radius."



Covalent radius can be deduced from the measurement of interatomic spacing by means of x-rays. In the following example, the bond distance between the two atoms "A" and "B" is the average of the lengths A-A and B-B.



Q4: Define ionization energy. What are the factors which affect I.E? What are the trends of I.E in periodic table?

Ans. Ionization Energy / Ionization Potential:
(BISE Malakand 2018, Kohat 2019)

Definition: "The minimum amount of energy required to remove an electron from the valence shell of an isolated gaseous atoms is called ionization energy or ionization potential." Experimentally ionization energy of an element is measured in joule/atom or kilo joul/mol.

Examples:

$Na_{(g)} \xrightarrow{Energy} Na^{+}_{(g)} + 1\bar{e}$ I.E = +496Kj/mol

$Mg_{(g)} \xrightarrow{Energy} Mg^{+1}_{(g)} + 1\bar{e}$ I.E = +738Kj/mol

- Ionization energy may be 1st, it may be second and it can also be 3rd ionization energy.
- The amount of energy required to remove 1st

electron from the valence shell of an isolated gaseous atom is called 1st ionization energy while the amount of energy required to remove 2nd electron from the valence shell of an isolated gaseous atom is called 2nd ionization energy. It is represented by I.E.

Example:

$Mg \longrightarrow Mg^{+1}$ I.E = +738Kj/mol

$Mg^{+1} \longrightarrow Mg^{+2}$ I.E = +1450Kj/mol

- 2nd ionization energy is greater / higher than the 1st ionization energy.

Ionization Energies (in Kj/mol) for Periods 1,2,3:

Period 1			Period 2							
	H	He	Li	Be	B	C	N	O	F	Ne
IE_1	1312	3272	520	900	801	1086	1402	1314	1681	2081
IE_2		5250	7298	1757	2427	2353	2856	3388	3374	3952
IE_3			11815	14849	3660	4621	4578	5300	6050	6122
			Period 3							
			Na	Mg	Al	Si	P	S	Cl	Ar
IE_1			496	738	578	787	1010	1000	1251	1521
IE_2			4562	1451	1817	1577	1903	2251	2297	2666
IE_3			6912	7733	2745	3232	2912	3361	3822	3931

Factors Affecting Ionization Energy:

(Bannu 2019)

Ionization energies of atoms depend upon the following factors:

- Atomic radius of the atom
- Nuclear charge of the atom
- Shielding effect of the underlying electrons

- Electronic configuration

1. Larger the atomic size / atomic radius, lower will be the ionization energy and smaller the atomic size, higher will be the I.E value.
2. Higher / greater the nuclear charge, higher will be the ionization energy and vice versa.
3. Greater the shielding effect, lower will be the ionization energy and vice versa (اس کے برعکس).
4. Elements having half filled and full filled sub-shells are more stable and have high ionization energy values.

Trends of Ionization Potential in Periodic Table:

Ionization potential decreases from top to bottom [down the group]. It is because going from top to bottom, the number of shells increases. Distance between nucleus and valence electrons increases and thus attractive force decreases. So little amount of energy will be required to remove the valence electron.

Ionization potential value increases from left to right along the period. It is because going from left to right, nuclear charge increases force of attraction between nucleus and valence electrons increases. Thus greater amount of energy will be required to remove electron.

1st Ionization Energies of the Normal Elements:

H 1312							He 2372
Li 520	Be 899	B 801	C 1086	N 1402	O 1314	F 1681	Ne 2081
Na 496	Mg 738	Al 578	Si 786	P 1012	S 1000	Cl 1251	Ar 1521
K 419	Ca 590	Ga 579	Ge 762	As 947	Se 941	Br 1140	Kr 1351
Rb 403	Sr 549	In 558	Sn 709	Sb 834	Te 869	I 1008	Xe 1170
Cs 376	Ba 502	Tl 589	Pb 716	Bi 703	Po 812	At 1002	Rn 1038

EXAMPLE 3·2: Which atom in each of the following sets has the largest ionization energy?

a. K, Ga, Se b. O, S, Se

c. In, As, Cl

Solution:

a. "Se" has the largest I·E value because it is smaller in size and present at the right side of the periodic table.

b. Oxygen has the largest I·E value because of its small atomic size as compared to S and Se. Oxygen is present at the top of its own group.

c. Chlorine has the highest I·E value as compared to Indium and Arsenic. It is because chlorine is present at the right side as well as at the top as compared to the other two elements.

We know that elements present at the top and to the right side have small atomic sizes.

PRACTICE PROBLEM 3.3:

Which atom in each of the following sets has the largest ionization energy?

a. Be, C, N b. Mg, Ca, Sr

c. Sn, Fe, F

Ans: We know that atoms present to the right and top of the periodic table have small atomic sizes and will have large I.E values so among the above three sets of elements Nitrogen, Magnesium and Fluorine has the largest I.E values.

Can you explain the abnormalities in ionization potential values from Be – B and N – O on the basis of their electronic structure and shielding effect?

Ans: The symbols, atomic numbers and the electronic configuration of period-2 elements is given below:

Li^3	Be^4	B^5	C^6	N^7	O^8	F^9	Ne^{10}
$1s^2,2s^1$,	$1s^2,2s^2$	$1s^2,2s^2,2p^1$	$...2p^2$	$...2p^3$	$...2p^4$	$...2p^5$	$...2p^6$

We know that elements having half filled and fulfilled sub-shells are more stable than those elements having partially filled sub-shells. More stable elements have high I.E values.

Looking into the electronic configuration of the above elements Beryllium (Be) has fulfilled sub-shell and the p-sub-shell of Nitrogen is half filled. So these are more stable and have high I.E values as compared to B and O.

TEST YOURSELF

Hydrogen Lithium Sodium Potassium

- *Use a periodic table, to complete the last two diagrams for sodium and potassium.*
- *What do you notice about the number of electrons in the valence energy level in each case?*
- *Explain why elements from group-IA are more reactive than elements from group-IIA of the periodic table. [Hint: thing back to ionization energy]*

Ans.

H^1	Li^3	Na^{11}	K^{19}
K=1	K=2, L=1	K=2, L=8, M=1	2,8,8

So we will complete the last two diagrams according to the above electronic configuration.

- From the above electronic configuration as well as from the group number (IA) of these elements it is clear that they have one electron each in their valence shells.
- Group-IA elements have larger atomic sizes as compared to group-IIA elements. Similarly the I.E values of IA group elements are lower than the I.E values of IIA group ele-

ments. It means that IA group elements will lose electrons easily as compared to IIA group elements and thus are more reactive than group IIA elements.

Q5: What is electron affinity? What are the various factors which affect electron affinity? Explain its periodicity in periodic table. (BISE Mardan 2019)

Ans. **Electron Affinity (E.A):** [Affinity means love/attraction]

Definition: "The amount of energy released during the addition of an electron to the valence shell of an isolated gaseous atom is called electron affinity".

Electron affinity means love or attraction for accepting electrons. It is denoted by E.A. Elements possess varying tendencies towards the acceptance of electrons is their outer shell. The new incoming electron when absorbed by the atom is slightly bound by the nucleus of the atom through attractive force. This cause release of energy, thus the electron affinity of the atom is measured in terms of energy. It is measured in the unit of kj/mole.

Examples:

$F + 1\bar{e} \longrightarrow F^{-1}$ E.A = -337 Kj/mol

$Cl + 1\bar{e} \longrightarrow Cl^{-1}$ E.A = -348 Kj/mol

$O + 1\bar{e} \longrightarrow O^{-1}$ E.A = -141 Kj/mol

Electron affinity may be, 1st electron affinity and it can also be 2nd electron affinity.

The energy released during the addition of 1st electron to the valence shell of an atom is called 1st electron affinity. It is assigned negative value.

The energy absorbed by the addition of 2nd electron to the valence shell of an isolated gaseous atom is called second electron affinity ($E.A_{II}$).

The second electron affinity has a positive value because energy is added / required to overcome the electron-electron repulsion.

$$O + 1\bar{e} \longrightarrow O^{-1} \quad E.A_{I} = -141\ Kj/mol$$

$$O^{-1} + 1\bar{e} \longrightarrow O^{-2} \quad E.A_{II} = +780\ Kj/mol$$

Factors Affecting Electron Affinity:

(BISE Swat 2019)

The following factors affect electron affinity.

1. Nuclear charge
2. Atomic size / radius
3. Electronic configuration
4. Shielding effect

- Greater the magnitude of nuclear charge within the same period, higher will be the electron affinity value and vice versa (اس کے برعکس).
- Larger the atomic size / radius lower will be the electron affinity and vice versa.
- Elements having half filled and fulfilled sub-shells have low electron affinities.

- Poor the shielding effect, lower will be the electron affinity.

Periodicity / Variation in Periodic Table:

(Mardan 2017)

Variation in a Group: Electron affinity decreases from top to bottom in a group due to increase in atomic size and also increase in shielding effect. When we move from top to bottom [down the group] new shells are continuously added. These shells make a shield (ڈھال) between nucleus and the incoming electron, so force of attraction decreases and thus E.A decreases.

Variation in a Period: Electron affinity increases from left to right along the period. It is due to increase in nuclear charge and decrease in atomic radius. Therefore the tendency of taking electron increases.

1st Electron Affinities of the Normal Elements:

1A (1)							8A 18
H 72.8	2A (2)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	He +21
Li 59.6	Be +241	B -26.7	C -122	N 0	O -141	F -328	Ne +29
Na 52.9	Mg +230	Al -42.6	Si -134	P -72.0	S -200	Cl -349	Ar +34
K 48.4	Ca +156	Ga -28.9	Ge -119	As -78.2	Se -195	Br -325	Kr +39
Rb 46.9	Sr +167	In -28.9	Sn -107	Sb -103	Te -190	I -295	Xe +40
Cs 45.5	Ba +52	Tl -19.3	Pb -35.1	Bi -91.3	Po -183	At -270	Rn +41

Q6: What is shielding effect? Explain its periodicity in periodic table.

Ans. **Shielding Effect:**

(BISE Mardan 2018, Kohat 2019)

Definition: "The decrease in the attractive force of the nucleus on the valence electrons due to the presence of inner shell electrons is called shielding effect."

We know that the electrons are evenly distributed around the nucleus in various shells. The inner shell electrons shield (بچاؤ) the outer electrons from the nuclear charge. The valence electrons spend most of the time away from the nucleus than the inner shell electrons, because these electrons do not feel the full effect of the positive charge of the nucleus. As the number of shells increases shielding/screening effect will be increased and there will be more protection of valence electrons from nuclear attraction. So the removal of valence electrons will become easy.

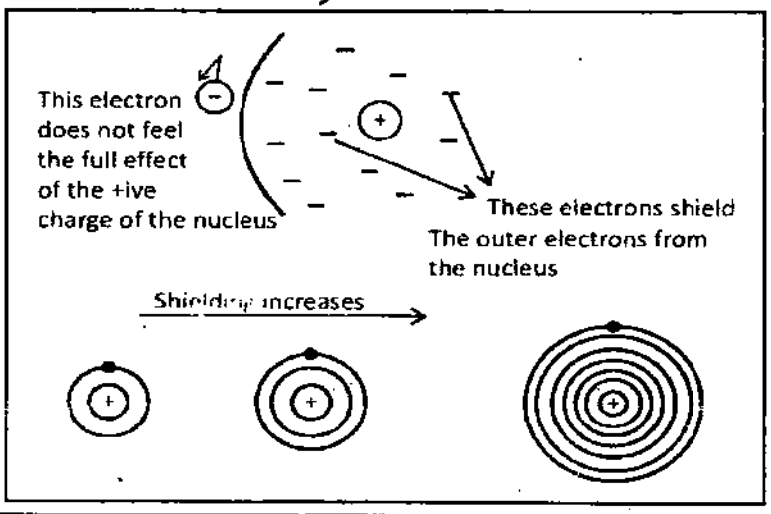
Shielding effect is responsible for the decrease in the force of attraction between the nucleus and valence shell electrons. Shielding effect has a direct impact (اثر) on the atomic radii, ionization potential and electron affinities of the elements.

Variation of Shielding Effect in Periodic Table:

Shielding Effect in Groups: When we move in a group from top to bottom, the shielding effect is more effective than the nuclear charge. This is

because a new shell is added as we move down in the group. This shell screens the valence electrons from the hold of the nucleus. This causes a decrease in the ionization energies and electron affinities of the elements down the group.

Shielding Effect in Periods: When we move in a period from left to right, the atomic number increases. Positive charge on the nucleus increases. The number of electrons in the valence shell also increases but shell remains the same. Consequently (∴) the increasing nuclear charge wins over shielding effect, which remains constant. This results decrease in atomic radii, increase in ionization energy and electron affinity values of elements.



Q7: What is electronegativity? What factors affect electro-negativity? Explain its periodicity in periodic table.

Ans. **Electro-negativity (E.N):**

Definition: "The ability of an atom to attract

the shared pair of electrons towards itself in a covalent bond is called electronegativity." If a covalent bond is formed between two similar atoms the shared pair of electrons are equally attracted to both the nuclei and such a covalent bond is said to be non-polar.

H-H ⊕⊕ [non-polar bond]

On the other hand if the bond is formed between atoms having different electronegativities [abilities], the atom with higher electronegativity attract the shared pair of electrons more towards itself and will get a slight negative charge ($-\delta$) and the other atom will get a slight positive charge ($+\delta$). Such a bond is called polar covalent bond. For example covalent bond in HCl molecule is polar.

$H^{+\delta}$ - $Cl^{-\delta}$ [Polar covalent bond]

Factors Affecting Electro-Negativity [E.N]: (Bannu 2019)

1. **Atomic Size:**

Larger the size of the atom, smaller will be the electro-negativity and smaller the atomic size, higher will be the electro-negativity value.

2. **Nuclear Charge:**

Greater the nuclear charge higher will be the electronegativity and smaller the nuclear charge lower will be the electro-negativity.

3. **Shielding Effect:**

Greater / higher the shielding effect lower will be

the electro-negativity value of that atom.

4. Electronic Configuration:

Atoms having half filled sub-shells and fulfilled sub-shells are stable. The addition of electrons to these sub-shells is difficult. On the other hand, atoms having almost filled sub-shells are more electronegative than others.

Pauling calculated the electronegativities values of the elements. For this purpose, he developed a scale from bond energies of diatomic molecules. On this scale the electronegativity of fluorine is 4.0 which is the highest of all the periodic table elements. The lowest value is for cesium which is 0.7.

Electro-Negativity Values of some other elements are:

H = 2.1	Li = 0.98	Be = 1.57
B = 2.01	C= 2.55	N = 3.04
O = 3.5	F = 4.0	Cl = 3.16
Br = 2.96 ≅ 3	I = 2.66	Na = 0.93
Mg = 1.31	Al = 1.81	Si = 2.02
P = 2.19	S = 2.58	etc.

Trends in Periodic Table:

Variation in Group: Electronegativity decreases from top to bottom [down the group]. It is due to increasing size and increasing shielding effect.

Variation in a Period: Electronegativity increases from left to right along the period. It is due to

decrease in atomic size and increase in nuclear charge due to the increase in atomic number.

TEST YOURSELF

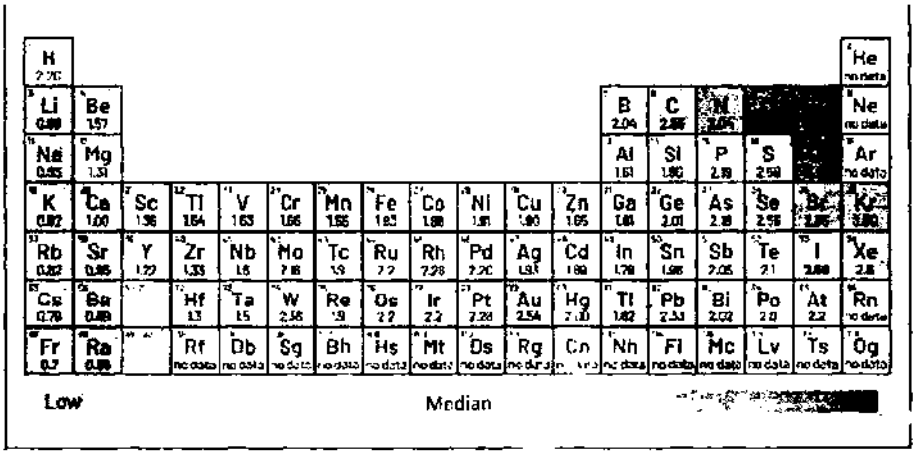
The least electronegativity element is cesium (0.7) can you guess, where is it located in the table?

Ans. Cesium is located at the extreme left and bottom of the periodic table. It is the element of IA-group and 7th period.

Can you tell, elements of which group have the highest electro-negativity values?

Ans. Elements of VIIA group [halogens] in periodic table have the highest electronegativity values.

Electronegativity Trend in Periodic Table:



EXAMPLE 3.3: Which set has the more similar properties?

a. N, P, As b. Li, C, F

Solution:

Set (a) has the more similar chemical properties. because these elements are in the same group. We

know that elements of the same group has almost similar properties.

Set (b) elements are in the same period.

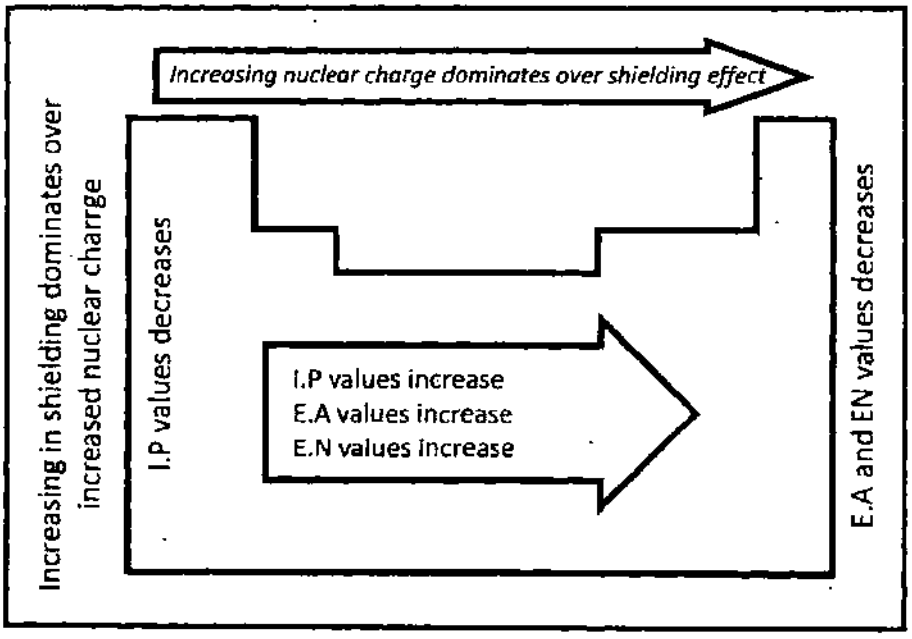
PRACTICE PROBLEM 3.4:

Is sulphur more likely to be similar to selenium (Se) or to chlorine in its chemical properties?

Solution:

We know that elements present in the same group have similar outermost shell / sub-shell electronic configuration and have the same chemical properties. So sulphur is more likely to be similar to selenium in its chemical properties because both are the elements of the same group.

Periodicity of Shielding Effect, I.P, E.A and E.N:



Exercise

Choose the correct option:

1. Which of the following elements is in the same family as fluorine?
   (a) Silicon (b) Antimony
   (c) Iodine✓ (d) Arsenic
2. Which of the following would have the smallest ionization energy?
   (a) K (b) P
   (c) S **(d) Ca✓**
3. An element has configuration 2, 8, 1, it belongs to:
   (a) Group IA and 3rd period✓
   (b) Group IIIA and 1st period
   (c) Group IA and 7th period
   (d) Group VIIA and 3rd period
4. Which of the following elements would be most similar to carbon?
   (a) Nitrogen (b) Boron
   (c) Oxygen **(d) Silicon✓**
5. S-block elements are:
   (a) Metals✓ (b) Non-metals
   (c) Metalloids (d) Transition
6. Which of the following would have the largest ionization energy?
   (a) Na (c) Al
   (c) H **(d) He✓**
7. Elements in a.....have similar chemical prop-

erties.

(a) Period (b) Group✓

(c) Both (a) & (b) (d) None

8. An element has 8-electrons in its valence shell. It is a member of:

(a) Alkali family (b) Halogen family

(c) Noble family✓ (d) Carbon family

9. Modern periodic table is based on:

(a) Atomic number✓

(b) Mass number

(c) Neutron number

(d) Isotope number

10. Shielding effect is due to:

(a) Neutron

(b) Proton

(c) Proton and neutron

(d) Electron✓

Short Questions

Answer briefly the following questions:

Q1: Which element of group IA is not an alkali metal and why?

Ans. Hydrogen of group IA is not an alkali metal because it does not form alkalies when reacts with water. It is not a metal because it does not possess the properties of metals like shiny surface, ductility, malleability and conductivity.

Q2: Place the following elements in order of increasing ionization energy. Na, S, Mg, Ar

Ans. The order of increasing ionization energy for the given elements is:

Na	<	Mg	<	S	<	Ar
496		738		1000		1521Kj/mol

Q3: Name the group and state the group numbers of each of the following elements:
(a) K (b) Ne (c) Be (d) Cl (e) C

Ans.

a) K: Group IA, alkali metal group
b) Ne: Group VIIIA, noble gases [zero group]
c) Be: Group IIA, alkaline earth metals
d) Cl: Group VIIA, halogens
e) C: Group IVA, carbon family

Q4: Which element is the most electronegative among C, N, O, Br and S? which group does it belongs to?

Ans. Oxygen is the most electronegative element and it belongs to VIA group.

Q5: How do the 1st ionization energies of representative elements vary (تبدیل) across a period and down a group?

Ans. Ionization energies increases from left to right in a period because left to right atomic size decreases and nuclear charge increases. Similarly, ionization energies decrease down the group. It is because down the group atomic size increases.

Similarly attraction between nucleus and valence electron decreases.

Q6: Which element is found in:
(a) Period-2, group VIIA
(b) Period-4, group IIIA
(c) Period-5, group VIA
(d) Period-1, group VIIIA

Ans.

a) Fluorine is present in period-2, group VIIA.
b) Gallium is present in period-4, group IIIA.
c) Tellurium is present in period-5, group VIA.
d) Helium is present in period-1, group VIIIA

Q7: How will you differentiate between representative and transition elements?
(Mardan 2019)

Ans.

1. Sub-group-A elements in periodic table are called representative elements while sub-group-B elements in periodic table are called transition elements.
2. Representative elements have fixed oxidation states while transition elements have variable oxidation states.
3. Representative elements consist of metals, non-metals and metalloids while the transition elements are all metals.
4. s and p-block elements are representative elements while d-block and f-block elements

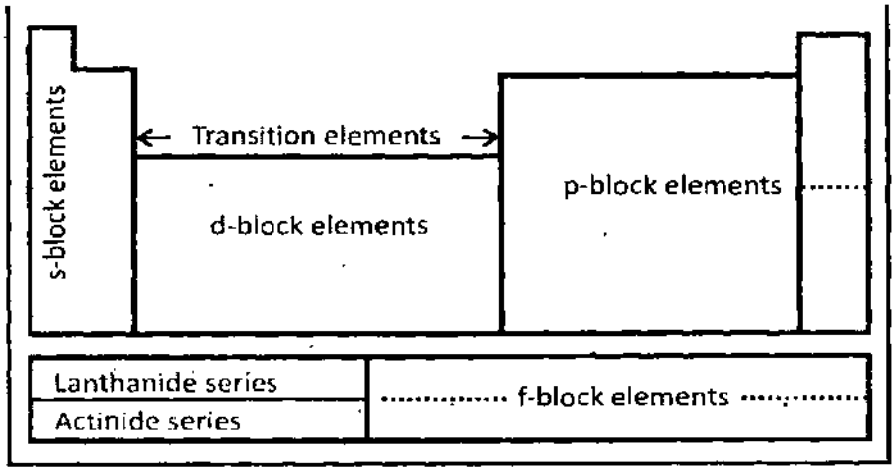
are called transition element.

5. Compounds of transition elements are mostly coloured while those of representative elements are often coloured.

6. All transition elements are solid [except mercury] while representative elements exist in all the three states of matter.

Q8: Make a general sketch of periodic table showing s, p, d and f-block elements, without showing the symbols of elements.

Ans.



Q9: Why the s-block elements have two groups only?

Ans. As s-sub-shell can accumulate two electrons so only two groups have been included in s-block category.

Q10: What type of element is sulphur (S), a representative element, a transition element or lanthanide element?

Ans. $S^{16} \rightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^4$

From the electronic configuration of sulphur it is clear that the last electrons enter into p-subshell or p-subshell is in the process of completion, so it is a p-block element. We know that representative elements consist of s and p-block elements. So sulphur is a representative element. (OR) Simply "sulphur" is a sub-group-A element so it is a representative element. It is present in VIA group of the periodic table.

Long Questions

Q1: How modern periodic table is different from the Mendeleev's periodic table?

Ans: Mendeleev's periodic table was based on increasing order of atomic weight and modern periodic table is based on atomic numbers.

- In Mendeleev's periodic table there were vacant spaces for undiscovered elements and there are no vacant spaces in modern periodic table.
- In Mendeleev's periodic table the position of isotopes was not clear while it is quiet clear in modern periodic table. As isotopes have the same atomic numbers so they occupy only one position in periodic table.
- Mendeleev placed alkali metals and coinage metals in one group which possess different properties. In modern periodic table these elements were separated. Alkali metals are in IA group and coinage metals are in IB group.

- In Mendeleev's periodic table position of halogens and noble gases was not clear but in modern periodic table halogens and noble gases have their own groups (i.e. VIIA and VIIIA).

Q2: Differentiate between atomic radii and covalent radii. Explain the trends of atomic radius in periodic table.

Ans. Please See question # 3.

Q3: What is electronegativity? Identify the most and least electronegative elements in the periodic table. Why is fluorine special in terms of electronegativity?

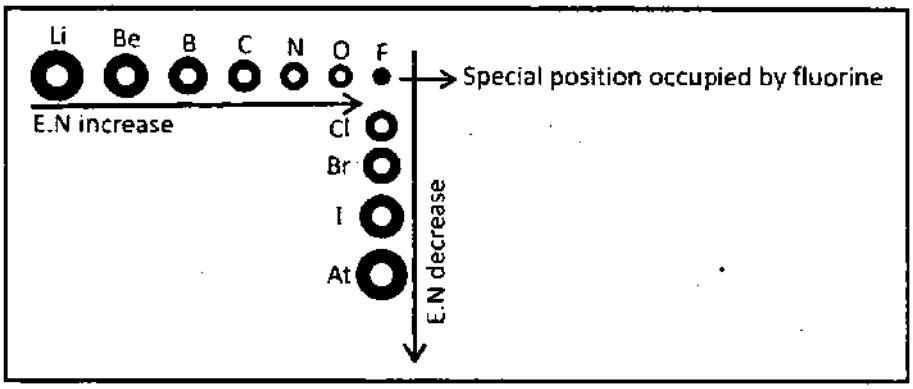
Ans. "The tendency of an atom to attract the shared pair of electrons towards itself in a covalent bond is called electro-negativity."

The most electronegative element in periodic table is fluorine and the least electronegative element is cesium.

Fluorine has the highest electronegativity in the whole periodic table and special in this term because it is small in atomic size. Similarly, it occupies a special position in periodic table i.e. right and top position.

We know that going from left to right along the period electro-negativity increases. As fluorine is on the right extreme so it has maximum electronegativity. When we go drown in a group the electronegativity value decreases, so from fluorine

to astatine decreases again.



Q4: Define shielding effect and draw its affects on the ionization energy, electron affinity and electronegativity.

Ans. Shielding Effect:

"The decrease in the attractive force between nucleus and valence electrons due to the presence of inner shell electrons is called shielding effect."

Effect of Shielding Effect on Ionization Energy:

Higher the shielding effect lower will be the ionization energy value and lesser the shielding effect higher will be the ionization energy, values of element.

Effect of Shielding Effect on Electron Affinity:

Greater the shielding effect, lower will be the electron affinity and lesser the shielding effect higher will be the electron affinity values.

Effect of Shielding Effect on Electronegativity:

Greater the shielding effect, lower will be the electronegativity and lesser the shielding effect, higher will be the electronegativity values of atoms.

In nut shell (مختصراً) greater the shielding effect,

lower will be the ionization energy values, electronegativity values and electron affinity values and vice versa.

Q5: Explain the following:

a. Periodicity of properties
b. Electron affinity (E.A)
c. Modern periodic law

Ans. (a) Please see question # 2
(b) Please see question # 5
(c) Please see question # 1

❑❑❑

"If you rest, you will rust, if you work, you will shine, and if you shine the world will give you credit."

- اللہ تعالیٰ سے محبت کا اِحساس اِتنا خالص اور خوبصورت ہے کہ اگر ایک بار محسوس کر لیا جائے تو پھر کسی کی محبت ضروری نہیں رہتی۔
- قدر کرنی ہے تو زندگی میں کرو، میت اُٹھاتے وقت تو نفرت کرنے والے بھی رو پڑتے ہیں۔
- میرے اچھے وقت نے دنیا کو بتایا کہ میں کیسا ہوں اور میرے بُرے وقت نے مجھے بتایا کہ دنیا کیسی ہے۔

CHAPTER 4

Structure of Molecules

Introduction:

"The attractive force which keeps species together in a substance is called a bond." Except noble gases which exist as atoms, all other elements and compounds are formed by the combination of atoms. Atoms combine and form molecules. Molecules of the same elements consist of the same kind of atoms e.g. O_2, O_3, P_4, S_8 etc, while chemical compounds are made up of different kinds of atoms/ions e.g. H_2O, CO_2, CH_4 etc. The process by which atoms join together and then combine together is called chemical bonding.

Why do atoms form chemical bonds?

We know that every system in the universe goes towards stability and tends to lower its energy. For example water flows from higher level to lower level. Electricity flows from higher potential to lower potential. Heat flows from a hot body to a cold body. Air flow from higher pressure region to lower pressure region. All these happens because water and electricity are trying to decrease their energy.

The energy of the isolated hydrogen atoms is higher than the bonded hydrogen atoms. That is the combination of atoms gives stable molecule through emission of energy. They can decrease their energy by combining with other atoms and form a chemical bond.

Q1: Explain the following:
- **a. The valence concept**
- **b. The orbital concept**

Ans. There are two concepts which explain the chemical bond formation.

1. **The Valence Concept: [Electronic theory of valence]** (BISE Peshawar 2019)

In 1916 Gilbert Newton Lewis [G.N Lewis] an American physical chemist and W. Kossel gave the electronic theory of valence. It states that in a chemical bond formation, atoms take part by losing, gaining or sharing of electrons so as to attain the inert or noble gas electronic configuration when atoms have two or eight electrons in their outermost shells, they are stable. The electron theory of valence can be named as the octet or duplet theory of valence.

a. Octet Theory of Valence (OR) Rule of Eight:

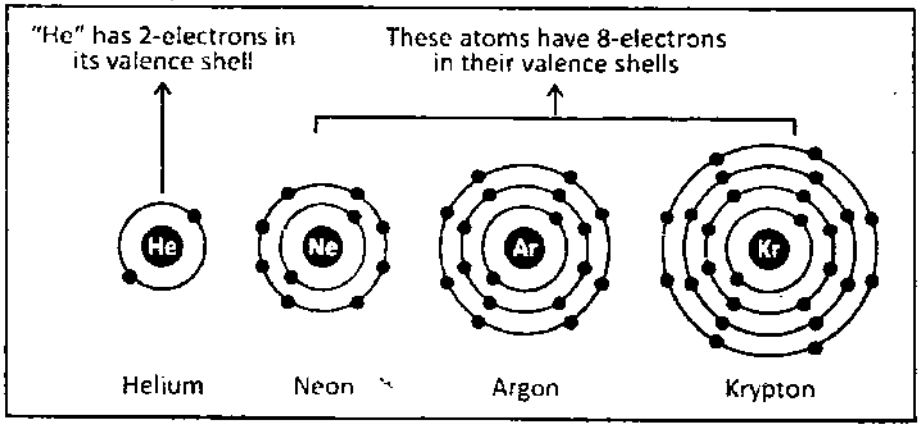
Rules of eight explain the tendency of atoms to have eight electrons in the outermost shell in order to attain stability. (OR)

Simply the desire of an atom to have electrons

in the last shell is called octet rules. For example oxygen atom has six electrons in its valence shell. It shares or gains two electrons in its outermost shell and attains the stability by completing its outermost shell with eight electrons.

b. Duplet Rule or Rule of Two:

Definition: "The tendency of an atom to have two electrons in the valence shell in order to get stability is called duplet rule or rule of two." For example, hydrogen has one electron in its outermost shell. It gets one electron or shares its one electron to complete its valence shell by two electrons to get stability. Similarly Helium has two electrons in its valence shell and is stable. Elements in group VIIIA of the periodic table [noble gases] have complete duplet [He] and octet [Ne, Ar, Kr, Xe] and therefore are stable. They rarely take part in chemical reactions to form compounds.



2. **The Orbital Concept:**

This concept is based on the combination of

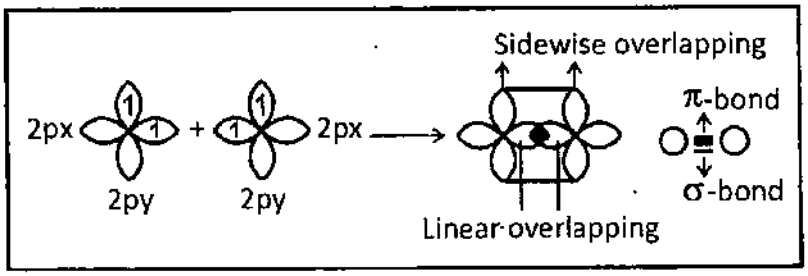
atomic orbitals to produce molecular orbitals. The atomic orbitals which have one electrons each when come close to each other. They overlap each others. In this way the atomic orbitals are completed by two electrons. Linear overlapping of atomic orbitals results in the formation of a sigma bond while sidewise overlapping of atomic orbitals results in the formation of pi (π) bond.

For example:

$O^8 = 1s^2, 2s^2, 2p^4$

$O^8 = 1s^2, 2s^2, 2px^1, 2py^1, 2pz^2$

$O^8 = 1s^2, 2s^2, 2px^1, 2py^1, 2pz^2$



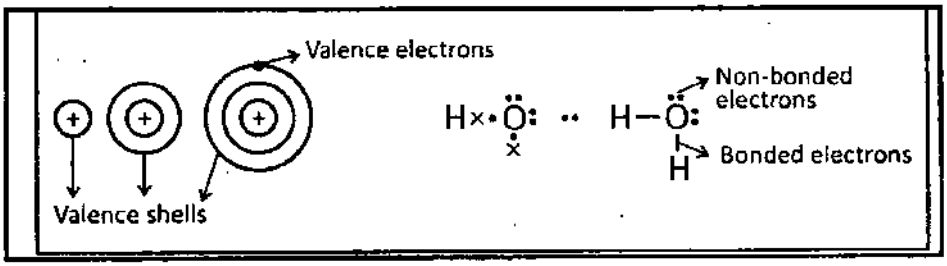
SCIENTIFIC INFORMATIONS

Valence Shell: The last shell of an atom is called valence shell / outermost shell.

Valence Electrons: Electrons present in the valence shell of an atom are called valence electrons.

Bonded Electrons: Electrons taking part in bond formation are called bonding electrons.

Non-Bonding Electrons: Electrons which do not take part in bond formation are called non-bonding/lone pair of electrons.



Q2: Define chemical bond and chemical bonding. What are the various types of chemical bonds?

Ans. **Chemical Bond:**

"The attractive force which keeps atoms together in a stable molecule or opposite ions in a compound is called chemical bond."

Chemical Bonding:

"The way by which atoms join together and then combine together is called chemical bonding." (OR) the process of formation of chemical bond is called chemical bonding.

Types of Chemical Bonds:

There are four types of chemical bonds:

1. Ionic bond or electrovalent bond
2. Covalent bond or electrons pair bond
3. Coordinate covalent bond / dative bond
4. Metallic bond

Q3: What is an ionic bond? Explain with the help of examples.

Ans. **Ionic Bond / Electrovalent Bond:**

(BISE Malakand 2018, Abbottabad 2019)

Definition: "The type of chemical bond which is formed by the complete transfer of electron(s)

from one atom to another atom is called an ionic bond / electrovalent bond." (OR)

"The electrostatic attraction between the oppositely charged species is called an ionic bond."

Explanation: The transfer of electrons between atoms complete the octets and duplets. Ionic bond is always formed between a metal and a non-metal. Metals always lose electrons to form cation and non-metals always gain electrons to form anion. During ionic bond formation metal atom loses electrons and non-metallic atom gain electrons. Then an electrostatic force of attraction is set up between oppositely charged ions. This force holds opposite ions together. This attractive force s called an ionic bond.

The atom having low ionization energy value will lose one or more electrons to form cation while the atom having high electron affinity will gain one or more electrons to form anion.

EXAMPLES No.1: Formation of NaCl:

Sodium contains 11 electrons. Its electronic configuration is given as;

Na^{11} (2, 8, 1)

Na^{11} ($1s^2$, $2s^2$, $2p^6$, $3s^1$)

(i) It loses one electron from its valence shell and attain [get] the electronic configuration of Ne-10 [a noble gas].

Na^{11} (2, 8, 1) $\longrightarrow$ $Na^+ + 1\bar{e}$

$1s^2$, $2s^2$, $2p^6$, $3s^1$ $\qquad$ $(2,8) \rightarrow 1s^2, 2s^2, 2p^6$

(ii) Chlorine contain 17-electrons, having the electronic configuration given below:

Cl^{17} [2, 8, 7] or $1s^2, 2s^2, 2p^6, 3s^2, 3p^5$

Chlorine picks up one electron and get the electronic configuration of argon-18 [a noble gas].

$Cl^{17} + 1\bar{e} \longrightarrow \bar{Cl}$

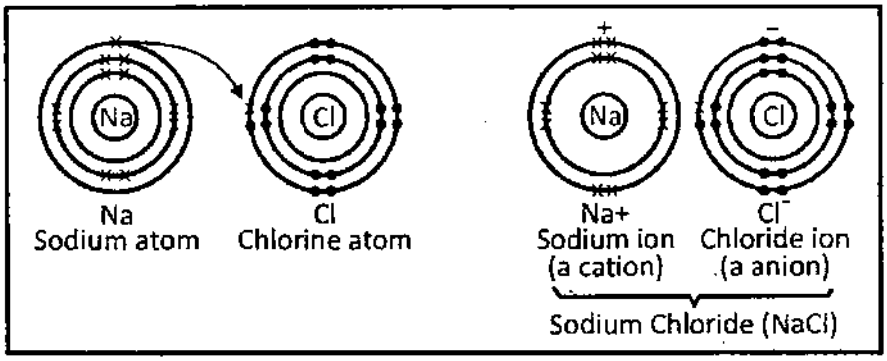
(2,8,7) (2,8,8)

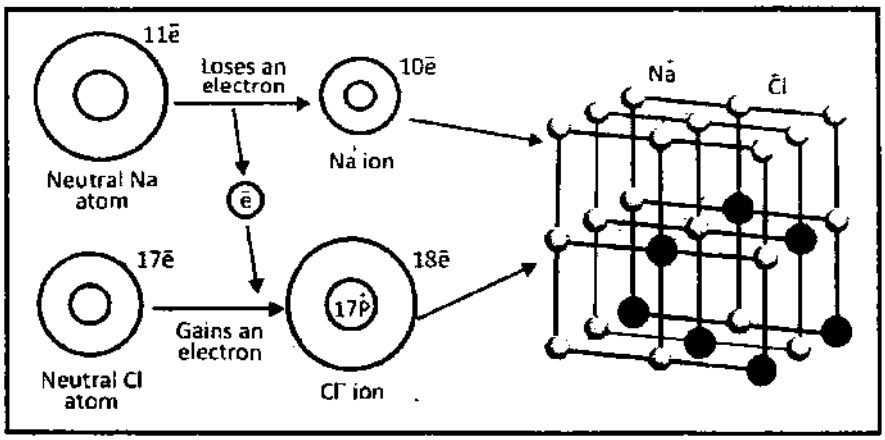
$(1s^2, 2s^2, 2p^6, 3s^2, 3p^5)$ $(1s^2, 2s^2, 2p^6, 3s^2, 3p^6)$

(iii) Then the positively and negatively charged ions attract each others by electrostatic force of attraction and form an ionic bond.

$Na^+ + \bar{Cl} \longrightarrow Na^+\bar{Cl}$ or $NaCl$ (OR)

$\dot{Na} + \dot{Cl} \longrightarrow NaCl$





EXAMPLES No·2: Formation of $CaCl_2$:

(i) Calcium loses two electrons to form dipositive ions·

$Ca \longrightarrow Ca^{+2} + 2\bar{e}s$

(2,8,8,2) (2,8,8)

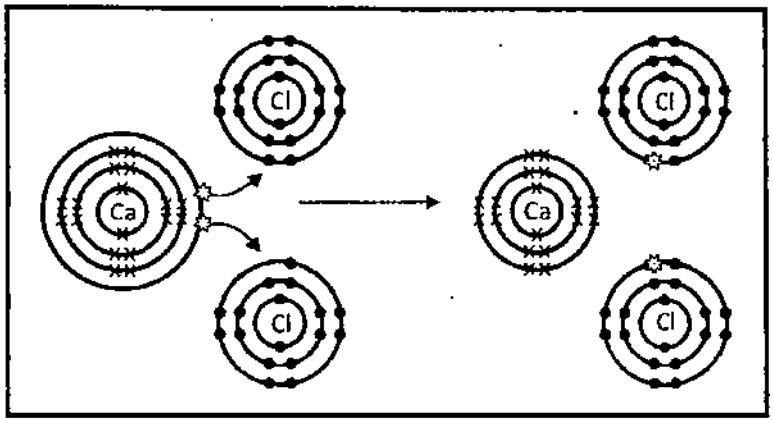
(ii) Chlorine get one electron for the completion of its valence shell· As calcium loses two electrons so, two chlorine atoms pick up these two electrons and gets the electronic configuration of argon-18 [noble gas]·

$2Cl^{7} + 2\bar{e} \rightarrow 2C^{-1}l$

(2,8,7) (2,8,8)

(iii) Then one Ca^{+2} and $2C^{-1}l$ ions combine to form an ionic compound $CaCl_2$·

$Ca^{+2} + 2C^{-1}l \rightarrow CaCl_2$



TEST YOURSELF

1· In what ways do atoms form ions?

Ans· Atoms form ions by losing and gaining of electrons·

2. Ionic bonds are formed between which two types of elements?

Ans: Ionic bonds are formed between metals and non-metals [good electron loses and good electron acceptors].

3. State the formula of the ions formed by the following atoms: (a) Calcium (2,8,8,2), (b) Fluorine (2,7), (c) Lithium (2,1), (d) Oxygen (2,6)

Ans: a: $Ca(2,8,8,2) \longrightarrow Ca^{+2}(2,8,8) + 2\bar{e}$

b: $F + 1\bar{e} \longrightarrow F^{-1}$

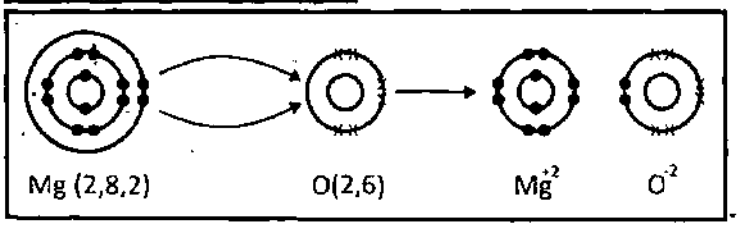
(2,7) (2,8)

c: $Li\ (2,1) \longrightarrow Li^{+1}(2) + 1\bar{e}$

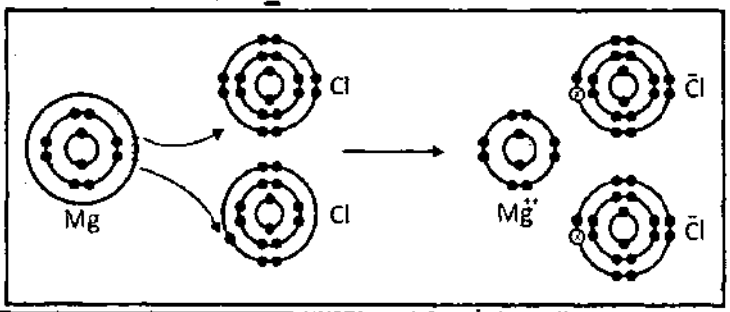
d: $O(2,6) + 2\bar{e} \longrightarrow O^{-2}(2,8)$

4. Draw a diagram to show the ionic bonds in magnesium oxide (MgO) and magnesium chloride ($MgCl_2$).

Ans: Formation of MgO:



Formation of $MgCl_2$:



Why do atoms form ions?

Ans· Atoms form ions in order to complete their duplet and octet as they can't complete their valence shell by electron sharing·

Q4: Explain covalent bond with the help of examples·

Ans· **Covalent Bond:**

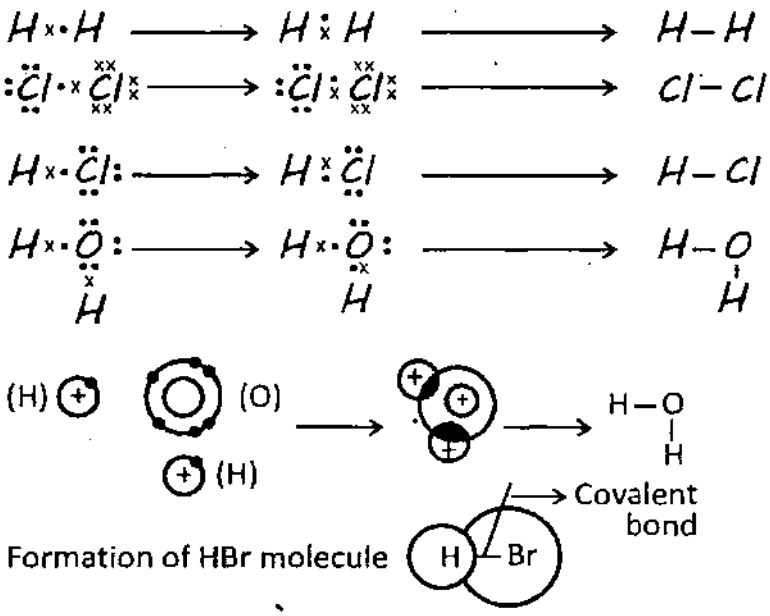
(Peshawar 2019)

Definition:

"The type of chemical bond which is formed by the equal sharing or natural sharing of electrons between two atoms is called a covalent bond·"

It is also called an electron pair bond· The shared pair of electrons is indicated by a dash (-), between two bonded atoms· Covalent bond was introduced by G· N Lewis· The energy of the covalently bonded atoms is always less than the separated atoms· Thus a covalent molecule / compound is more stable than the separated atoms· The shared pair of electrons remains between the two bonded atoms· These shared electrons are called localized electrons· Covalent bonds are formed between two non-metals·

Examples:



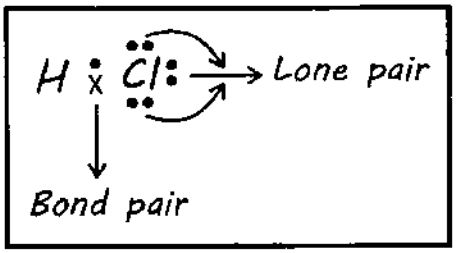
SOCIETY, TECHNOLOGY & SCIENCE

Glue is a substance that causes two surfaces to be bonded together. The term is commonly used interchangeably with adhesive. An adhesive holds materials together. There are different types of adhesive e.g. cement, glue etc. There are many natural and synthetic adhesives in use. Adhesives can also be used as coatings on the surfaces that are subjected to corrosion and rust. Adhesives are also used in many repair applications. These are commonly used to fix broken dishes and to make other repairs that would be impossible or difficult by other means. This can also provide improved mechanical strength. A pop-

ular application of adhesives is to encapsulate electronic components, providing protection for that component against environmental and mechanical damage.

EXAMPLE 4.1: Draw an electron dot and cross diagram for HCl. Label the single bond and the lone pair.

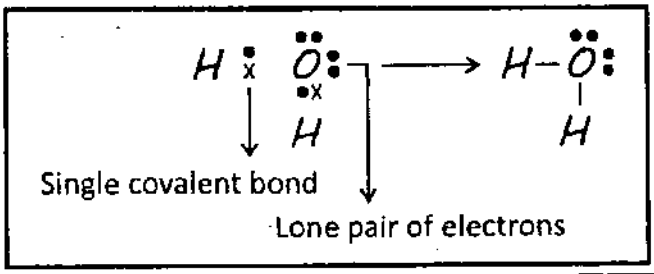
Solution:



PRACTICE PROBLEM 4.1:

Draw an electron dot and cross diagram for H_2O. Label the single bond and lone pairs:

Solution:



Q5: Explain single covalent bond, double covalent bond and triple covalent bond. (Mardan 2019)

Ans. "Depending upon the shared pair of electrons a covalent bond may be:

1. Single covalent bond
2. Double covalent bond

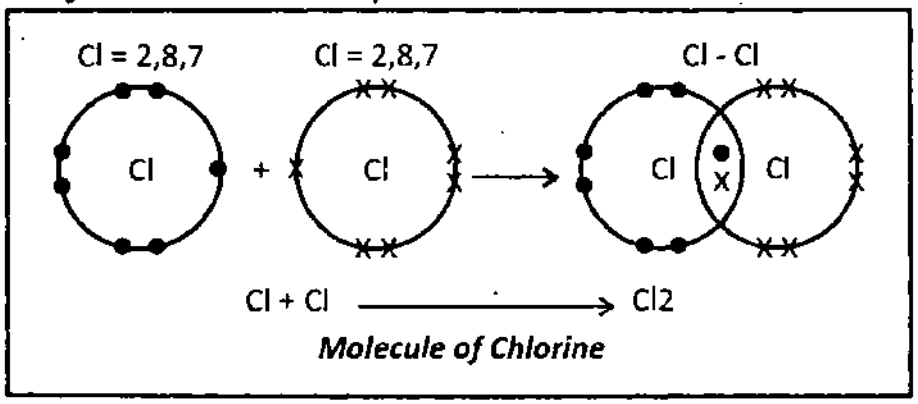
3· Triple covalent bond

1· Single Covalent Bond:

Definition: "A covalent bond which is formed by the equal sharing of one-one electron or one electron pair is called a single covalent bond·" It is represented by a single straight line·

Examples: H_2, Cl_2, F_2 etc·

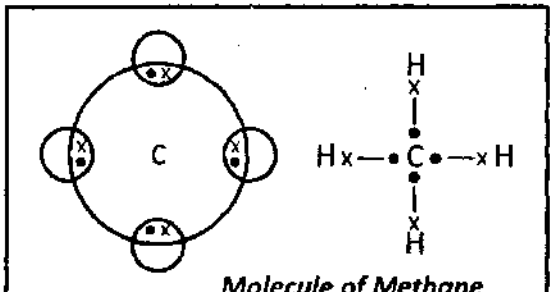
(a) Cl_2: Chlorine molecule is formed from two chlorine atoms· The electronic configuration of chlorine atom is Cl-17 [2, 8, 7]· A chlorine atom has seven electrons in its valence shell· The two chlorine atoms mutually shares one-one electron with each other to form chlorine molecule [Cl_2]· Therefore, both chlorine atoms attain inert gas (Ar) electronic configuration and complete their octet·



Molecule of Chlorine

(b) Molecule of Methane, CH_4 [At· No· H=1, C=6):

Carbon has four electrons in its outermost shell and needs four more electrons to attain the noble gas [Ne] configura-



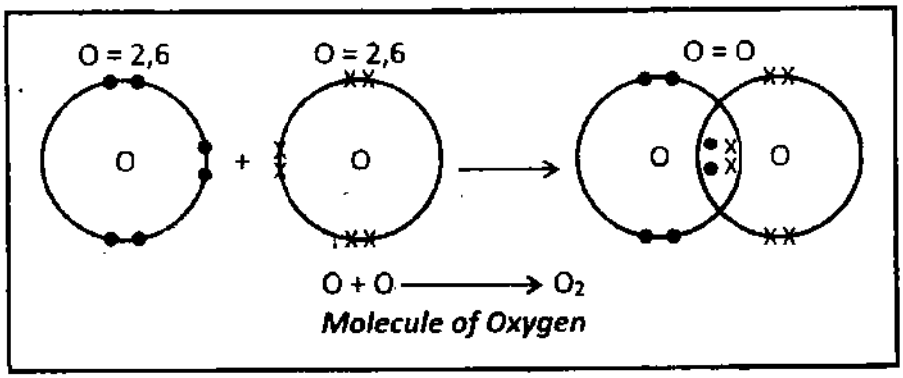
Molecule of Methane

tion. Therefore four atoms of hydrogen equally share one electron each with a carbon atom and form four single covalent bonds.

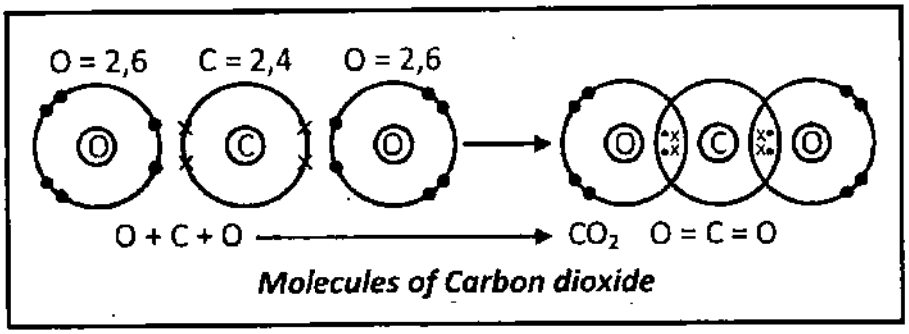
2. Double Covalent Bond:

Definition: "The type of covalent bond which is formed by the mutual sharing of 2, 2 electrons or two electron pairs is called a double covalent bond." It is denoted / represented by two straight lines (=). Examples are O_2, C_2H_4, CO_2 etc.

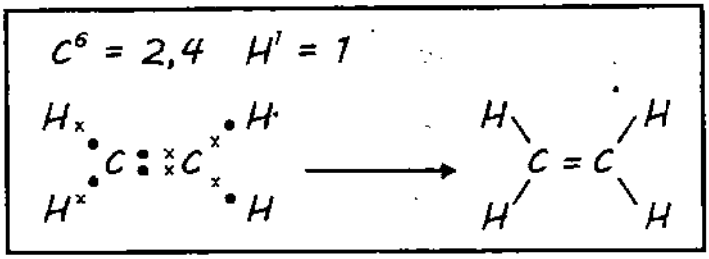
(a) Oxygen Molecule: Oxygen molecule is formed from two oxygen atoms. The electronic configuration of oxygen atom is O^8 (2,6). An oxygen atom has 6 valence electrons. It shares two electrons with another oxygen atom to form oxygen molecule (O_2). In this way both oxygen atoms attain inert gas [Ne] electronic configuration and complete their octet.



(b) Carbon Dioxide [CO_2]: In carbon dioxide molecule formation, carbon atom shares four electrons with two oxygen atoms and form two double covalent bonds.



(c) Formation of Ethene Molecule [C_2H_6]:

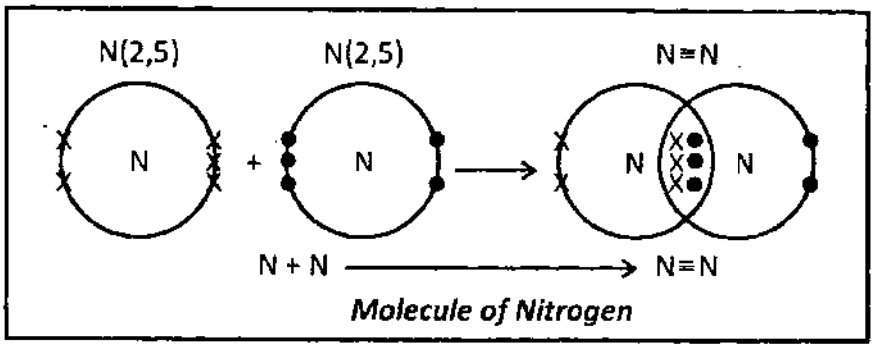


3. Triple Covalent Bond:

Definition: "The type of covalent bond which is formed by the equal sharing of total six electrons or three electron pairs is called a triple covalent bond." It is represented by three short straight line (≡). In a triple bond each atom contributes three electrons each.

EXAMPLES:

(a) Nitrogen [N_2]: Nitrogen molecule is formed from two nitrogen atoms. The electronic configuration of nitrogen N^7 = 2, 5. A nitrogen atom has five electrons in its valence shell and it shares three electrons with another nitrogen atom to form nitrogen molecule. In this way, both nitrogen atoms attain inert gas [Ne] electronic configuration and complete the octet.



Molecule of Nitrogen

(b) Formation of C_2H_2 [Acetylene] Molecule:

$C^6 = 2,4$ $H^1 = 1$

$$H \times\bullet C \overset{\bullet\times}{\underset{\bullet\times}{\vdots}} C \times\bullet H \longrightarrow H - C \equiv C - H$$

SCIENTIFIC INFORMATION

Sharing of electrons in the formation of covalent bonds rather than complete transfer from one atom to another atom as in the formation of ionic bonds depends upon the electro-negativity difference between the two bonded atoms. If electronegativity difference is less than 1·7, then bond will be covalent. If electronegativity difference is greater than 1·7 then the bond will be ionic. If electronegativity difference is equal to 1·7 then the bond will be 50% ionic and 50% covalent.

Activity 4·1

Classify the following substances as covalent or ionic. CO_2, $NaCl$, H_2O, C_6H_6, $MgCl_2$, HCl.

Solution:

Covalent compound = CO_2, H_2O, C_6H_6 and HCl

Ionic compound = $NaCl$ and $MgCl_2$
CO_2, H_2O, C_6H_6 and HCl are covalent because these are formed by the sharing of electrons between non-metallic elements.
$NaCl$ and $MgCl_2$ are ionic compounds because these are formed by the complete transfer of electrons from metallic elements to non-metallic elements.

EXAMPLE 4.2: Which one of the following is (1) uncombined atoms (2) molecules (3) and consist of ions?

(a) O_2 (b) Ne (c) NO_2
(d) KCl (e) Na_2O

Solution:

(a) O_2 → Molecule
(b) Ne → Uncombined atoms
(c) NO_2 → Molecule
(d) KCl → Consist of ions
(e) Na_2O → Consist of ions

PRACTICE PROBLEM 4.2:

Which one of the following is (1) uncombined atoms (2) Molecules and (3) consist of ions?

(a) H_2 (b) He (c) HCl (d) HgO

Solution:

(a) H_2 → Consist of molecules
(b) He → Consist of uncombined molecules
(c) HCl → Consist of molecules
(d) HgO → Consist of ions

Q6: What is coordinate covalent bond/dative bond? Explain with the help of examples.

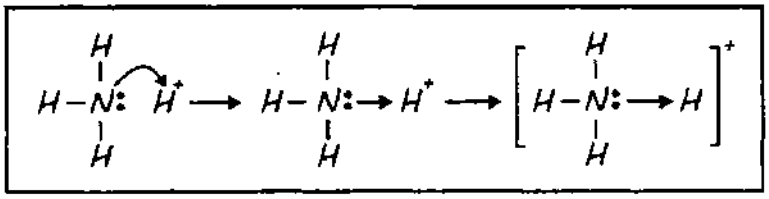
Ans. Coordinate Covalent Bond/Dative Bond:
(Mardan 2018, Kohat 2019)

Definition: "The type of chemical bond in which a shared pair of electrons is donated by only one atom or negative ion is called a coordinate covalent bond." It is also called a dative bond. A coordinate covalent bond is formed between those molecules in which one atom has excess [lone pair] of electrons and the other is electrons deficient (δ^+), having less than eight electrons in the valence shell. The atom which donates electron pair for bond formation is called a donor atom while the atom which accepts an electron pair is called an accepter atom. Coordinate covalent bond is represented by an arrow ($\rightarrow$) which is pointing from the donor atom towards the accepter atom. The resulting compounds having coordinate covalent bonds are called coordination compounds.

EXAMPLES:

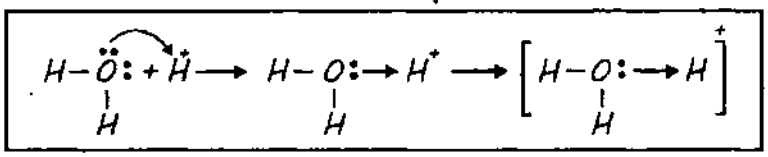
Formation of Ammonium Ion [N^+H_4]:

In ammonia molecule nitrogen atom has a lone pair of electrons which is donated to hydrogen ion [H^+], having no electrons at all and needs two electrons to complete its 1st shell. In this case nitrogen is donor atom and hydrogen ion [H^+] is accepter.



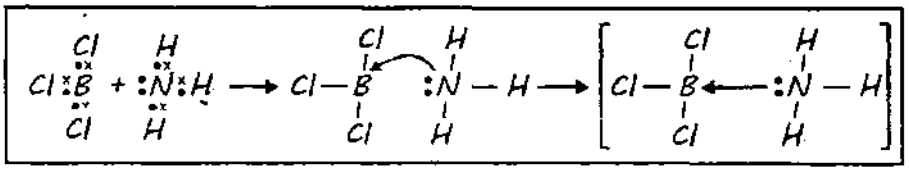
Formation of Hydronium Ion [H_3O^+]:

Oxygen atom in water molecule has two lone pair of electrons and donates it to hydrogen ion [H^+] and thus form hydronium ion. Here oxygen is donor atom and H^+ ion is accepter.

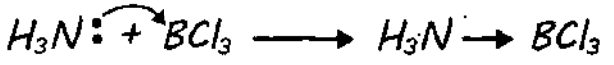


Addition Compound of NH_3 and BCl_3:

The nitrogen atom of ammonia ($\ddot{N}H_3$) has lone pair of electron and is electron rich specie. The Boron atom of BCl_3 is electrons pair deficient to complete its octet. Nitrogen donates lone pair of electrons to Boron and thus a coordinate covalent bond is formed. As a result an addition compound is formed, which is called aduct.



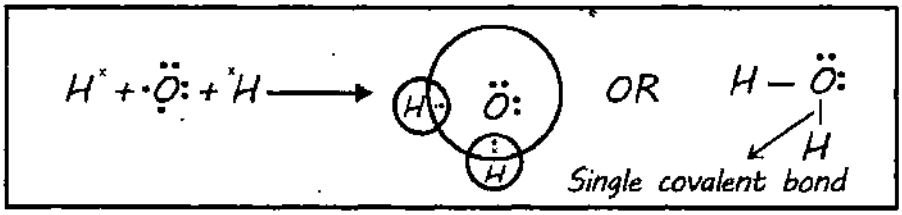
Simplify:



Lewis Structure: (Bannu 2019, Abbottabad 2019)

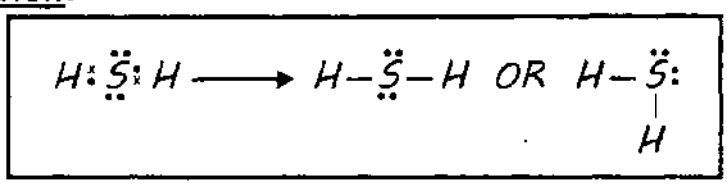
In Lewis structure, the lone pair / non-bonded electrons are represented by dots or cross and

shared pair of electrons are represented by line (-) between atoms. Lets draw Lewis structure for water molecule.



EXAMPLE 4.3: Draw the Lewis structure of hydrogen sulphide, H_2S.

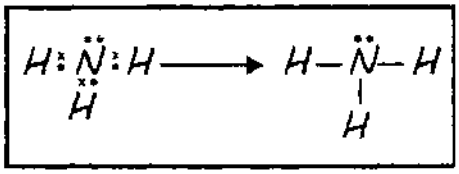
Solution:



Practice problem 4.3:

Draw the Lewis structure of NH_3 [ammonia].

Solution:



TEST YOURSELF

1. Which group of elements forms covalent bonds?

Ans. Non-metals [VIIA] form covalent bonds.

2. How is a covalent bond formed between two atoms?

Ans. A covalent bond is formed due to equal sharing of electrons between two similar or two

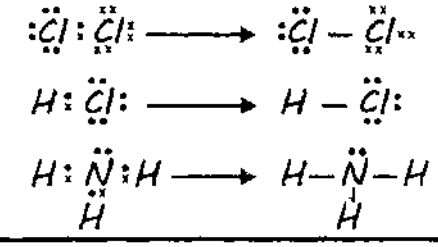
different atoms.

3. How many electrons are shared in a: (a) single covalent bond (b) double covalent bond?

Ans. Two electrons are shared in single covalent bond and four electrons are shared in double covalent bond.

4. Draw a dot and cross diagram to show the bonding in each of the following molecules. (a) Chlorine [Cl_2] (b) HCl (c) NH_3

Solution:



Q7: Explain polar and non-polar covalent bonds.

Ans. Depending upon the electronegativity values of the two bonded atoms or nature of the two bonded atoms, there are two types of covalent bonds.

1. Non-polar covalent bond
2. Polar covalent bond

Non-Polar Covalent Bond:

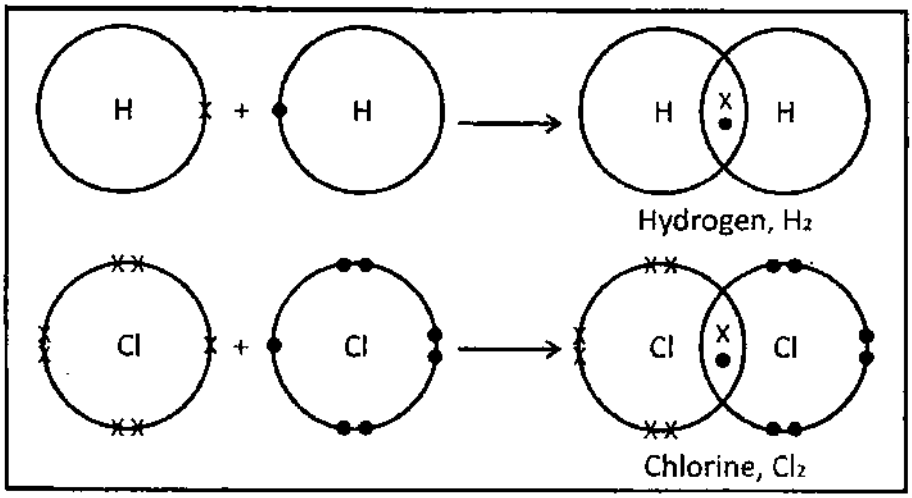
Definition: "The type of covalent bond which is formed by the equal sharing of electrons between two similar atoms is called a non-polar covalent bond." For example; H_2, Cl_2, N_2, O_2, Br_2 etc.

$$H \times \bullet H \longrightarrow H - H$$

$Cl \times \bullet Cl \longrightarrow Cl - Cl$

$Br \times \bullet Br \longrightarrow Br - Br$

$O^{\times}_{\times} :\!\overset{\bullet}{\underset{\bullet}{O}} \longrightarrow O = O$



In the above cases, the covalent bonds are 100% non-polar, because these bonds are formed between two similar atoms. The shared electrons are equally attracted to both the nuclei. Non-polar covalent bond can also be defined as "a covalent bond formed between two different atoms having electronegativity difference less than 0·4 or equal to 0·4." Example is CH_4.

In case of CH_4 [methane] the electronegativity difference between carbon and hydrogen is 0·4 so it is also a non-polar bond.

$C = 2{\cdot}5$

$H = 2{\cdot}1$

Difference = 0·4

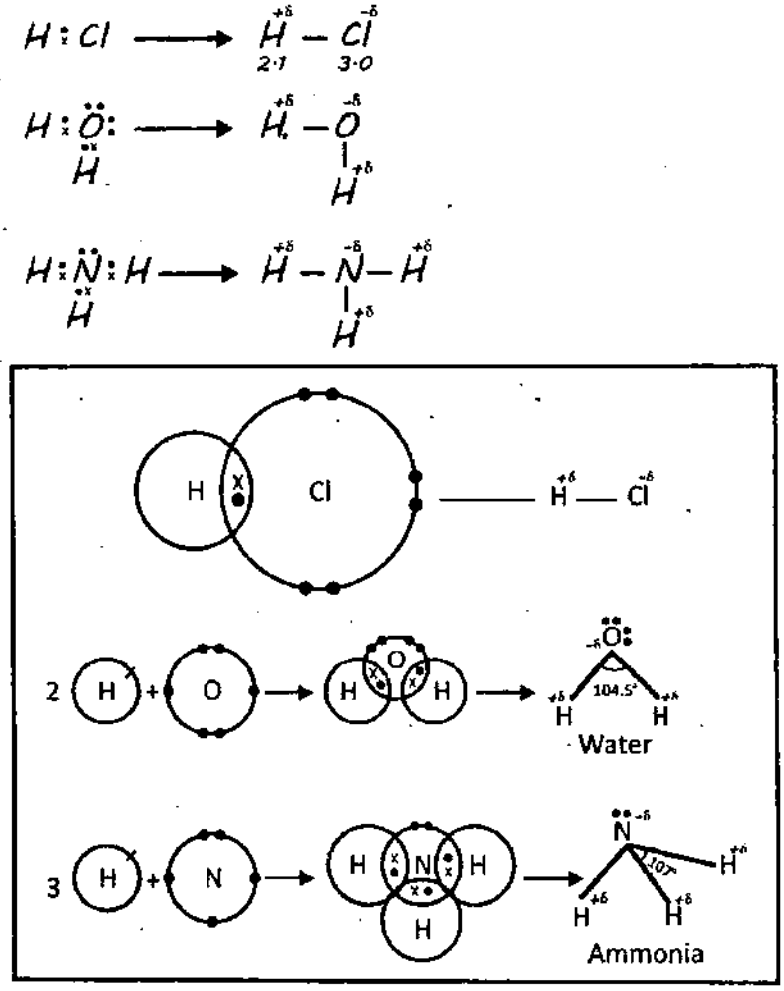
Polar Covalent Bond: *(Mardan 2018)*

Definition: *"The type of covalent bond which is*

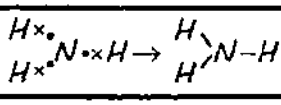
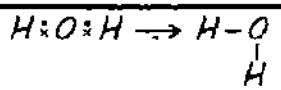
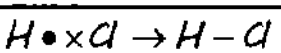
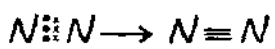
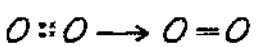
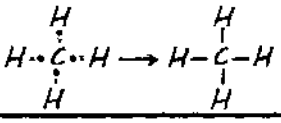
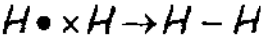
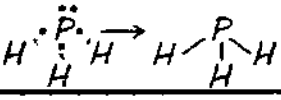
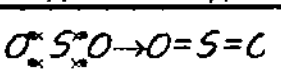
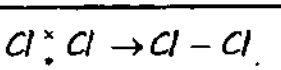
formed by the equal sharing of electrons between two different atoms having electronegativity difference greater than 0·4 is called a polar covalent bond·"

In case of different atoms, the atom with greater electro-negativity value attract the shared pair of electrons more towards itself and will get a partial negative charge while the other atom gets partial positive charge· Molecules with partial charges on atoms are called polar molecules·

EXAMPLES:



TEST YOURSELF

S.No.	Compound	Ch.symbol/ formula	Lewis Structure	Type of Bond
1.	Ammonia	NH_3		Polar bond
2.	Water	H_2O		Polar bond
3.	Hydrogen chloride	HCl		Polar bond
4.	Nitrogen	N_2		Non-polar
5.	Oxygen	O_2		Non-polar
6.	Methane	CH_4		Non-polar
7.	Hydrogen	H_2		Non-polar
8.	Phosphine	PH_3		Polar
9.	Sulphur dioxide	SO_2		Polar
10.	Chlorine	Cl_2		Non-polar

Q8: Explain metallic bond in detail.

Ans. Metallic Bond: (Mardan 2019)

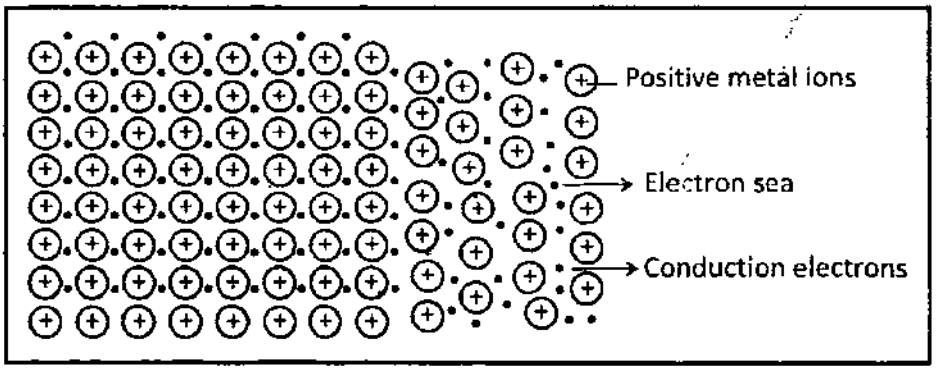
Definition: "The force of attraction between positively charged metallic nuclei and electrons gas/sea/cloud is called metallic bond." (OR)

"The chemical bonding that result from the attraction between metal positive ions and the surround-

ing sea of electrons is called metallic bonding."

In 1923, Lorentz put forward electrons gas or electrons sea theory. According to this theory valence electrons in metal atoms are generally loosely bound due to large atomic sizes of metal atoms and weak attractive force between nucleus and valence electrons. These loosely held electrons move freely. These are called conduction electrons. These free electrons form a pool or gas or sea around metal positive ions. These free electrons also create a negative atmosphere around the positively charged metals. There are two types of forces among the metals of metallic crystals. (BISE Abbottabad 2019)

1. Attractive forces among the electrons sea and positive ions.
2. Repulsive forces between the positively charged ions.



The metal ions are held together at the distance where attractive and repulsive forces balance each others. The free electrons do not belong to any single atom anymore and are set free to move

throughout the entire (کل) bulk (حجم) "body" of metal. No electron is allowed to escape from the bulk.

- Metallic bonds are neither ionic nor covalent, because they are neither formed due to electron transfer nor due to sharing of electrons between the atoms.
- Metallic bond does not result in the formation of a new molecule or compound.
- The metallic bond is present between metal atoms like aluminum [Al], silver [Ag], copper [Cu] and platinum [Pt] etc.

Activity 4.3

Identify ten (10) common substances in and around your home and indicate whether you would expect these substances to contain ionic covalent or metallic bonds?

Ans. The names of ten common substances in and around my home are:

1. Common salt [NaCl]
2. Sugar
3. Natural gas
4. Water
5. Iron
6. Silver
7. Oxygen
8. Polyethylene [plastic]
9. Vinegar [سرکہ]
10. Carbon dioxide [CO_2] gas

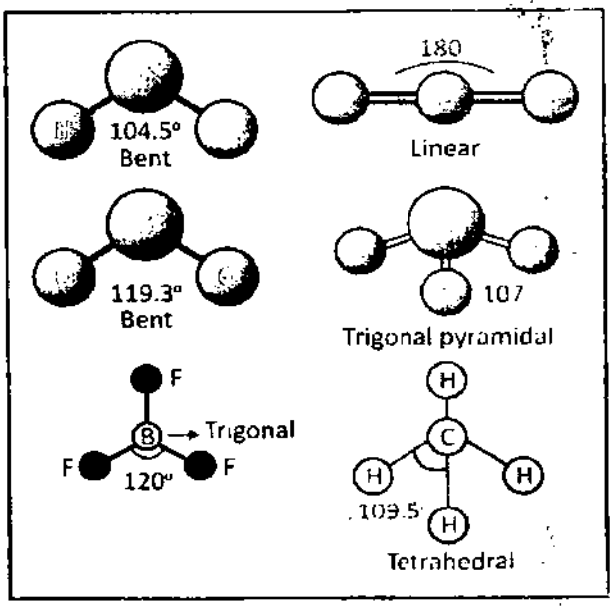
1. NaCl contains ionic bonds
2. Sugar contains covalent bonds
3. Natural gas [CH_4] contains covalent bonds
4. Water [H_2O] contains covalent bonds

5. Iron contains metallic bonds
6. Silver contains metallic bonds
7. Oxygen [O_2] contains covalent bonds
8. Polyethylene [$-CH_2-CH_2-]_n$ contains covalent bonds
9. Vinegar [CH_3COOH solution] contains covalent bonds
10. Carbon dioxide [CO_2] contains covalent bonds

Q9: Explain the shapes of some covalent molecules.

Ans. Shapes of Molecules:

Shape means the arrangement of atoms in a molecule and the angles between them. Molecules cannot be seen with naked eye, due to its extremely small size. However various experiments and analysis performed by scientists show that molecules have different shapes like linear, bent, triangular, tetrahedral, pyramidal and bipyramidal etc. For example, the molecular shape of



CO_2 is linear, the water molecule is angular, BF_3 has trigonal planer, CH_4 is tetrahedral and ammonia [NH_3] is trigonal pyramidal.

Q10: Write a note on intermolecular attractive forces. What are its types?

Ans. **Intermolecular Attractive Forces:**
(Mardan 2019)

Definition: "The forces which hold molecules together are called intermolecular attractive forces." (OR)
"The forces which bring the molecules close together and give them specific physical properties are called intermolecular attractive forces."
(OR)
"The forces of attraction present between molecules are called intermolecular attractive forces."

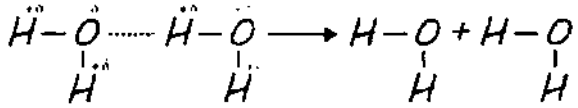
Explanation: Intermolecular forces are the weaker forces of attraction. These are 25 times weaker than the covalent bond. For example; for breaking hydrogen-oxygen covalent bond in water molecule, 464Kj/ mol energy is required while only 19Kj/mol energy is required to break intermolecular attractive force among water molecules.

$$H_2O \longrightarrow 2\dot{H} + \dot{O} \qquad \Delta H = 464 Kj/mol$$

OR $H - OH \longrightarrow \dot{H} + \dot{O}H$

$$H_2O_{(l)} \longrightarrow H_2O_{(g)} \quad 19Kj/mol$$

OR



Intermolecular attractive forces depend upon the distance between molecules. Longer the distance weaker will be the intermolecular attractive forces. That is why the intermolecular forces are much weaker among the molecules of gases, whereas these are stronger in the molecules of liquids and much stronger in solid molecules.

Intermolecular attractive forces affect the thermodynamic properties of substances. For example the melting point of solids and the boiling points of liquids depend on the strength of these forces.

Types of Intermolecular Forces:

There are three types of intermolecular attractive forces.

1. Dipole - dipole forces / interactions
2. Hydrogen bonding
3. London dispersion forces

Collectively these weak intermolecular attractive forces are called Vander Waal's forces.

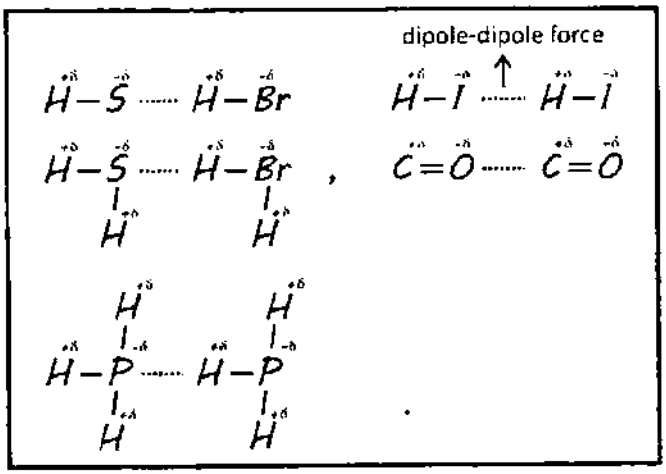
Q11: Write a detailed note on dipole - dipole interactions.

Ans. **Dipole - Dipole Forces:**

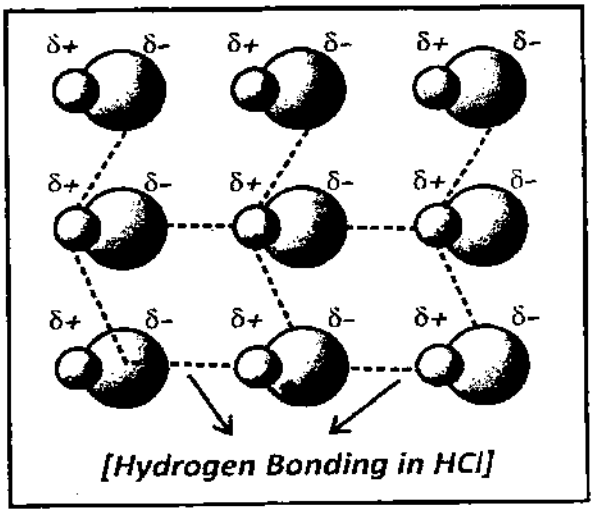
Definition: "The attractive forces between the positive pole of one dipolar molecule and the negative pole of another polar molecule are called dipole - dipole forces."

Explanation: Dipole - dipole force is one percent [1%] effective as compared to covalent bond. A

molecule having two oppositely charged poles is called a dipolar molecule or simply a dipole. e.g. $[H^{+\delta} - C^{-\delta}l]$



A polar molecule has partial negative charge on the more electronegative atom and a partial positive charge on the less electronegative atom. Example are NO, H_2S, H_2O, NH_3 and HCl.



Hydrochloric acid [HCl] is a polar molecule. It has partial positive charge on hydrogen atom and partial negative charge on chlorine atom. The partial positive hydrogen atoms of one HCl molecule attract the partial negative chlorine atom of another HCl molecule and thus a dipole - dipole force is set up. Dipole - dipole

interaction in HCl is relatively weak; only 3·3Kj/mole energy is required to break this interaction· The force of attraction between "HCl" molecules is so weak that hydrogen chloride [HCl] boils at -85C°·

The strength of dipole - dipole forces depend upon two factors:

1· Electronegativity difference between the two bonded atoms·

2· Distance between the two molecules·

- Higher the electronegativity difference between the two bonded atoms, stronger will be the dipole - dipole forces· For example, stronger dipole - dipole forces are present in HF molecules as compared to HCl molecules·
- Longer the distance between the molecules weaker will be the dipole - dipole forces·

Q12: Explain hydrogen bonding with the help of examples:

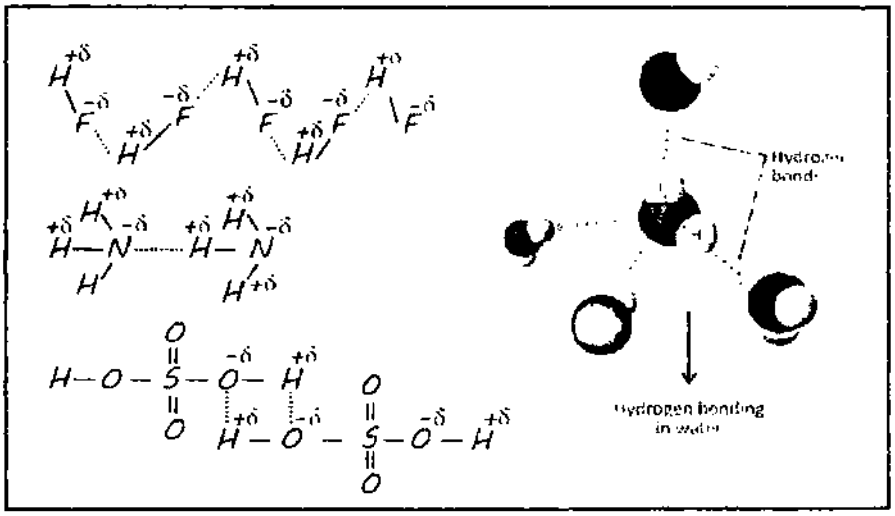
Ans· **Hydrogen Bonding:** (Peshawar 2019)

Definition: "The attractive force between the partial positive hydrogen atom of one molecule and the partial negative Oxygen, Fluorine or Nitrogen atom of the other molecule is called hydrogen bonding·" Hydrogen bond is represented by dotted lines [.....]· Hydrogen bond will be

present only in those molecules where hydrogen is directly attached to Oxygen, Nitrogen or Fluorine. There will be no hydrogen bonding among those molecules where hydrogen atom is attached to other atoms than Oxygen, Nitrogen and Fluorine.

The energy required to break hydrogen bonding is 25-33Kj/mole. The strength of hydrogen bond is twenty times less than that of a covalent bond.

EXAMPLES:



EXAMPLE 4.4: Which of the following form hydrogen bonds?

(a) HF (b) C_2H_4 (c) HBr

(d) N^+H_4 (e) H_2

Solution:

HF will form hydrogen bonds because here hydrogen atom is directly attached to a small sized highly electronegative fluorine atom which is the require-

ment of H-bond. (b, c, d, e) → C_2H_4, HBr, $\overset{+}{N}H_4$ and H_2 will not form hydrogen bonds, it is because in case of C_2H_4, HBr and H_2, hydrogen atoms are not attached to Nitrogen, Oxygen or Fluorine atom which is the requirement of H-bond.

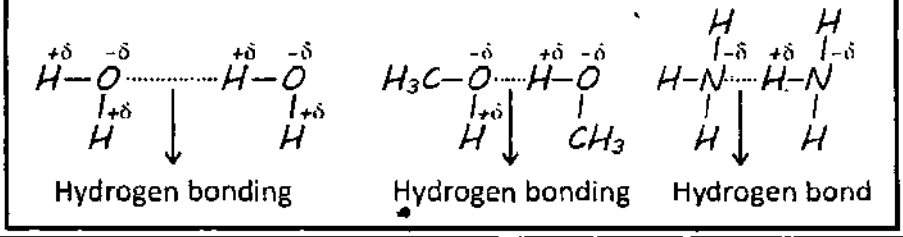
In case of $\overset{+}{N}H_4$, although hydrogen is directly attached to Nitrogen but Nitrogen atom has not partial negative charge as well as no lone pair of electrons.

PRACTICE PROBLEM 4.4:

Which of the following substances are expected to form hydrogen bonds?

(a) H_2O (b) CH_3OH (c) NH_3

Ans. All the three will form hydrogen bonds because in case of H_2O and CH_3OH, hydrogen is bonded directly to oxygen atom and in case of NH_3, hydrogen is directly attached to nitrogen atom which is the basic requirement of H-bonding.



Q13: Write down the applications of hydrogen bonding.

Ans. Applications of Hydrogen Bonding:

1. Hydrogen bonding explain the weak acidic

strength of HF as compared to HCl, HBr, HI.

2. Large protein molecules in living things are stabilized due to hydrogen bonding. For example fibres, hair and muscular proteins are stable due to hydrogen bonding.

3. Thousands of hydrogen bonds are present in DNA and RNA nucleotides, which give support to keep close the two helix twisted around each others.

4. Hydrogen bonding is present in paints (رنگ), dyes and glue which increase their adhesive (چپکنے والا) and sticky property.

5. Hydrogen bonding also stabilizes food materials like glucose, fructose, sucrose and carbohydrates.

6. Hydrogen bonding is present in thread (دھاگہ) like materials which increases rigidity (سختی) and tensil strength of thread.

7. The high boiling point of water (100C°) is also due to strong hydrogen bonding between water molecules.

Q14: Write down the properties of hydrogen bond.

Ans. Properties of Hydrogen Bond: (Kohat 2019)

1. Hydrogen bond is stronger than dipole - dipole forces and weaker than covalent bond.
2. It is twenty times weaker than a covalent bond.
3. Hydrogen bond is directional (سمتی).

4. Hydrogen bond results in the formation of long chains and network of molecules.

Q15: Write down the properties of ionic compounds.

Ans. **Properties of Ionic Compounds:**
(Malakand 2018)

1. Ionic compounds are solid at room temperature.
2. These are hard and brittle (ٹوٹنے).
3. These have high melting point and boiling values.
4. Soluble in polar solvents like water.
5. Good electrolytes in solution form and in molten state.
6. Conduct electricity in solution form as well as in molten state.
7. Their reactions are very fast in solution form.
8. They are non-volatile [non-evaporatable].
9. They have high densities.
10. Ionic compounds have non-directional ionic bonds.
11. Composed of cations and anions.

Q16: Write down properties of covalent compounds.

Ans. **Properties of Covalent Compounds:**
The properties of these compounds depend upon:

- Geometrical shape of molecules
- Polarity and intermolecular forces
- Type of bond [single, double, triple]

Some of the important properties are:

1. They have low melting point and boiling point values.

2. They are non-electrolytes in solution form.
3. The bonds in covalent compounds are directional.
4. The crystals of covalent compounds are composed of molecules.
5. Chemical reactions of covalent compounds are slower than those of ionic compounds.
6. Polar covalent compounds are soluble in polar solvents like water and Alcohol while non-polar covalent compounds are soluble in non-polar solvents like Benzene [C_6H_6], Acetone [C_3H_6O] and Carbon tetrachloride [CCl_4].

Q17: Write down properties of metallic compounds.

Ans. **Properties of Metallic Compounds:**
(Mardan 2019)
As metal atoms are held together by metallic bonds, due to metallic bond no new compound is formed so properties of metallic crystals will be the same to those of metallic elements.

1. All metals are solid at room temperature, and normal pressure except mercury [Hg] which is in liquid state.
2. They are malleable (مڑنے).
3. They are ductile (کھنچنے).
4. They are good conductors of heat and electricity.
5. They have shiny surfaces [lustrous].
6. They are sonorous [produces a specific sound

when beaten]

7. They are soft.

Malleable: Elements which can be drawn into sheets and foils when hammered in hot form / state.

Ductile: Elements which can be drawn into wires when stretched in hot form / state.

Sonorous: Elements which produces a ringing sound when struck with hummer (ہتھوڑا).

SCIENTIFIC INFORMATIONS

The greater the charges on the ions of an ionic compound, the higher will be its melting point. For this reason, the melting point of magnesium oxide [MgO] is 2800C°. So it can be used as refractory material for lining [coating] of furnaces (بھٹی). It means that it is fire proof.

Activity 4.4:

The 1st column in the table below lists some general properties of metals. Complete the 2nd and 3rd columns of the table.

General property of metals	Correct name for this property	One use that depends on this property
Can be drawn into wires.	Ductile	Electric wires

Can be bent into shape	Soft	Statues / utensils
Reflect light	De-excitation	Ornaments/jewellary
Make a ringing sound when struck	Sonorous	Musical wires
Allow electricity to pass through	Conductors	Used as electric wires
Transfer heat well	Good conductor	Cooking pots

- جس کی رات بیدار ہو جائے اس کا نصیب جاگ اُٹھتا ہے۔
- سکون یا اطمینان محنت کا نتیجہ نہیں، یہ نصیب کی عطا ہے۔
- عذاب کی اِنتہائی صورت یہ ہے کہ عذاب نازل ہو رہا ہو اور لوگ بدمستیوں اور رنگ رلیوں میں محو ہوں۔
- غافل کے لیے ساری کائنات حجاب ہے اور جاگنے والے کے لیے ساری کائنات اِنکشاف ہے۔
- غلام کو غلامی پسند نہ ہو تو کوئی آفت پیدا نہیں ہو سکتا۔
- ہم نے جن لوگوں کو اپنی موت کا غم دے کر جانا ہے کیوں نہ ان کو زندگی ہی میں کوئی خوشی دی جائے۔
- اچھے لوگ ان روشنیوں کی مانند ہوتے ہیں جو فاصلے کو کم تو نہیں کر سکتے مگر منزل آسان ضرور بنا دیتے ہیں۔

Exercise

Choose the correct option:

1. An atom with a charge is called:
   (a) An electron (b) A molecule
   (c) A metal **(d) An ion✓**
2. An element "X" in group VIA of the periodic table, the ion will be represented by:
   (a) X^{+} (b) X^{-}
   (c) X^{-2}✓ (d) X^{+2}
3. Which pair of elements will join to form a compound with one to one ratio?
   (a) Mg and Cl (b) Na and O
   (c) K and F✓ (d) Li and S
4. When calcium atoms become a calcium Ca^{+2} ion?
   (a) It loses an electron
   (b) It loses 2-electrons✓
   (c) It gains electron
   (d) Gains two electrons
5. Which two elements will form a covalent compound?
   (a) Na and O (b) Cu and O
   (c) C and O✓ (d) Mg and O
6. In the formation of ionic bond, the atoms taking part.
   (a) Only gain electrons
   (b) Share electrons
   (c) Lose and gain es✓
   (d) Only lose electrons

7. Fluorine has an electronic configuration 2, 7 and oxygen 2,6. The formula of fluorine oxide will be:
   (a) FO (b) F_2O✓
   (c) FO_2 (d) F_2O_2
8. Which of these elements about covalent bond is incorrect?
   (a) HCl contains one pair of shared electron
   (b) CCl_4 contains four pairs of shared electron
   (c) H_2O contains three pairs of shared electron✓
   (d) NH_3 contains three pairs of shared electron
9. Which of the following ions do not have the electronic configuration of an argon atom?
   (a) Ca^{+2} (b) S^{-2}
   (c) K^{+} (d) O^{-2}✓
10. Which one of the groups below contains only ionic compounds?
   (a) CaO, HCl, MgO
   (b) CaO, MgO, NaCl✓
   (c) CO_2, $CuSO_4$, HCl
   (d) $CuSO_4$, CH_4, NaCl

Short Questions

Answer briefly the following questions:

Q1: What is electron sea model of metallic bonding?

Ans. The model of bonding in metals, in which electrons are supposed to form a sea in which positively charged metal ions are floating and are

held together is electrons sea model.

Q2: Why most atoms are chemically bonded to each other atoms in nature?

Ans. The energy of the separated atoms is higher than the bonded atoms. It means that the combination of atoms give a stable molecule through emission of energy.

$\dot{H} + \dot{H} \longrightarrow H - H + E$

[Higher in energy & unstable] [lower in energy & stable]

Q3: Identify and define the four major types of chemical bonding.

Ans. The four major types of chemical bonds are: (1) ionic bond (2) covalent bond (3) coordinate covalent bond and (4) metallic bond.

1. **Ionic Bond:** "The attractive force which holds oppositely charged ions together in a stable compound is called ionic bond."

2. **Covalent Bond:** "The type of chemical bond which is formed by the equal sharing of electrons between two atoms is called a covalent bond."

3. **Coordinate Covalent Bond:** "The type of chemical bond in which the shared pair of electrons is donated by one atom is called a coordinate covalent bond."

4. **Metallic Bond:** "The force of attraction between metal atom ions and electrons sea is called a metallic bond."

Q4: Arrange the following from strongest to weakest attraction Covalent bond, Hydrogen bond, Iodine bond, dipole-dipole interactions.

Ans. Ionic bond > covalent bond > hydrogen bonding > dipole - dipole interactions.

Q5: Why ionic compounds are good electrolytes in molten and solution form and not in solid state?

Ans. Ionic compounds are good conductors in solution form or in their molten states. It is because there is a free movement of ions in solution form when electric current is passed through. We know that flow of ions. / charges is called current. Similarly, ionic compounds are bad conductors in their solid states because there is no free movement of ions in solid state.

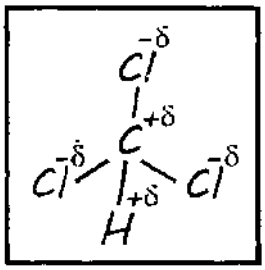
Q6: What type of elements / atoms tend to form the following types of bonding?
(a) Ionic (b) Covalent (c) Metallic

Ans. (a) **Ionic Bond:** Oppositely charged ions form ionic bonds or metals and non-metals form ionic bonds.
Covalent Bond: Non-metallic elements form covalent bonds.
Metallic Bond: Metallic elements form metallic bonds.

Q7: Give an example of a non-polar molecule with polar bonds. Give reasons.

Ans. CCl_4 is the example of a non-polar molecule

- with polar bonds.
  - The electronegativity of chlorine is greater than that of carbon so chlorine atoms get partial negative charge and carbon atom gets partial positive charge. Thus the carbon - chlorine bonds become polar.
  - Overall this molecule is non-polar because small sized partial positive carbon atom is surrounded by large sized partial negative chlorine atoms. Thus overall a negative atmosphere/ cover spread over the partial positive carbon atom and shield it. Thus the molecule becomes non-polar as a whole.



The Dipole Moment ~~of the molecule~~ is Zero so it is non-Polar. Other examples are CO_2, BF_3.

Q8: Predict the bond type [ionic, polar covalent, ~~non-polar~~ covalent] in each of the following:
(a) $CaCl_2$ (b) H_2O (c) CO_2 (d) C_2H_4

Ans.

(a) $CaCl_2$: contain ionic bond
(b) H_2O: contain polar covalent bond
(c) CO_2: contain polar covalent bond
(d) C_2H_4: contain non-polar covalent bond

Q9: Why ionic compounds are good conductors compared to covalent compounds?

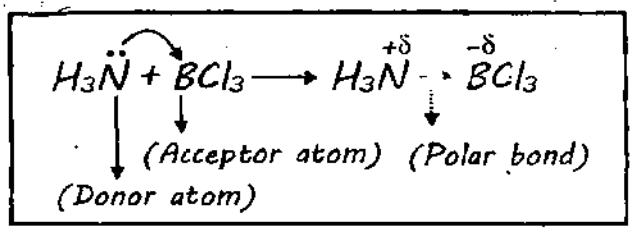
Ans. Ionic compounds are composed of ions and

good conductors in solution form due to free movement of ions. On the other hand covalent compounds do not contain ions and are bad conductors because there is no free movement of ions when electric current is passed through their solutions.

Q10: Give the reason that why dative bond is always polar?

Ans. Dative / coordinate covalent bond is always polar because in coordinate covalent bond, when the donor atom donate electrons pair for bond formation, deficiency of electrons creates on the donor atom and partial positive charge is created on the donor atom. Similarly when the accepter atom accept electrons pair for bond formation a partial negative charge is created on accepter atom and hence coordinate covalent bond becomes polar.

Example:



Long Questions

Q1: Describe the octet rules in terms of noble gas configurations and stability.

Ans: We know that noble gases are the elements of group VIIIA in periodic table. Noble gases can exist in free state under normal conditions of temperature and pressure. It is because the valence shells of noble gases are fulfilled which reflect their stability. The valence shell of helium [He] is complete by 2-electrons and the rest of noble gases have 8-electrons each in their valence shells.

Except noble gases, all other elements have incomplete valence shells and are unstable. For gaining stability [which is the rule of the universe], they gain, lose or share electrons to get the electronic configuration of noble gases.

Example:

$Ca^{20} \longrightarrow Ca^{+2} + 2\bar{e}s$

2,8,8,2 [2,8,8] electronic configuration of argon [noble gas]

$O^{8} + 2\bar{e} \longrightarrow O^{-2}$

2,6 2,8 → electronic configuration of neon [noble gas]

$Ca^{+2} + O^{-2} \longrightarrow CaO$

In this compound both Ca and O has the stable electronic configuration of noble gases and they have complete octet. "Ca" has completed its octet by losing two electrons and "O" has completed its

octet by gaining two electrons and thus "CaO" is a stable compound.

Q2: (a) What is the main distinction between ionic and covalent bonding?

Ans. The main difference between ionic and covalent bonding is that; ionic bonding occurs due to loss and gain or complete transfer of electrons from metal to non-metal and covalent bonding occurs due to equal sharing of electrons between two non-metallic elements.

Examples:

$Na^{11} \longrightarrow Na^{+1} + 1\bar{e}$

(2,8,1) (2,8)

$Cl^{17} \longrightarrow Cl^{-}$

(2,8,7) (2,8,8)

$Na^{+} + \bar{C}l \longrightarrow NaCl \rightarrow$ (ionic bonding)

$H : \underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}} : \longrightarrow H - Cl \rightarrow$ (covalent bond)

(b) How is electronegativity used in determining the ionic or covalent character of the bonding between two atoms?

Ans. Electronegativity difference between the two bonded atoms is helpful in determining the nature of a chemical bond.

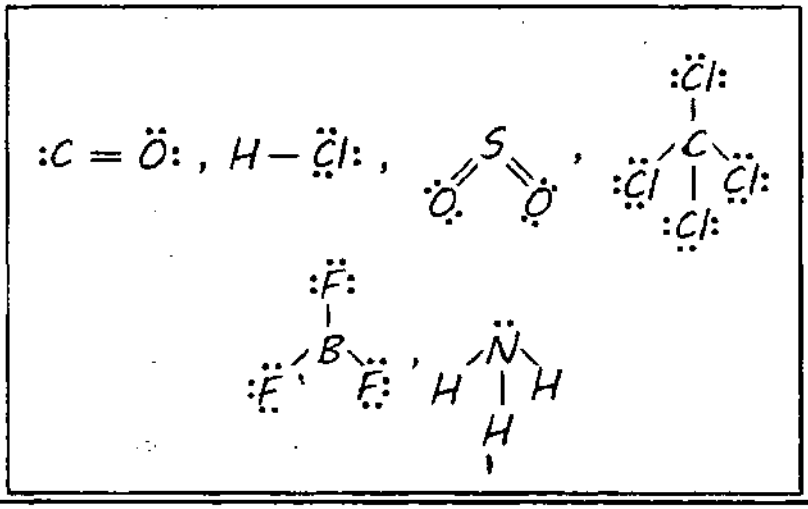
If E.N difference < 1.7 → bond is covalent

If E.N difference > 1.7 → bond is ionic

If E.N difference=1.7 → bond will be 50% ionic and 50% covalent

Q3: Draw the Lewis structure for each of the following compounds: (a) CO (b) HCl (c) SO_2 (d) CCl_4 (e) BFe (f) NH_3

Ans·



Q4: Explain why most metals are malleable and ductile but ionic crystals are not?

Ans· Most of the metals are malleable [can be drawn into sheets] and ductile [can be pulled out into wires]· This is because of the ability of the atoms to roll over each others into new positions without breaking the metallic bond· Secondly the energy is transferred throughout the rest of the metal by the moving electrons so these are malleable and ductile·

Ionic crystals are not malleable and ductile because ionic bonds in ionic crystals are very strong· The ionic crystals are tightly packed and cannot be compressed to be malleable or ductile· Ionic crystals break when hammered· These are brittle·

Q5: (a) What is the meaning of the term polar as applied to chemical bonding?

Ans· The term polar means a covalent molecule having partial negative charge on the more electronegative atom and partial positive charge on the less electronegative atom· The molecule is called polar molecule and covalent bonds in polar molecules are called polar bonds·

$\overset{+\delta}{H} - \overset{-\delta}{Cl}$ [polar covalent bond]

(b) Distinguish between polar covalent bond non-polar covalent bonds?

Ans· Please see question # 7·

❑❑❑

اقوال النبی ﷺ

- تم میں سے ہر ایک کو اپنی ساری حاجتیں اپنے رب سے مانگنی چاہئیں یہاں تک کہ چپل کا تسمہ ٹوٹ جائے تو بھی اس سے مانگو۔
- تم سے پہلی قوموں نے اپنے پیغمبروں اور بزرگوں کی قبروں کو اپنی عبادت گاہ بنالیا تھا۔ دیکھو تم نہ ایسا کرنا میں تم کو منع کرتا ہوں۔
- اللہ تعالیٰ سے پناہ مانگو اس دل سے جس میں عاجزی نہ ہو۔ ایسی دُعا سے جو سُنی نہ جائے اور ایسے نفس سے جو سیر نہ ہو۔
- دنیا کی محبت سب گناہوں کی جڑ ہے۔
- ملعون ہے وہ شخص جس کا اعتماد اپنے جیسی مخلوق پر ہے۔
- جس شخص کے دِل میں ذرہ برابر بھی ایمان ہوگا وہ دوزخ سے نکال لیا جائے گا۔
- ایسا بندہ برا شخص وہ ہے جس سے لوگ اپنے مال اور جان دونوں کو محفوظ سمجھیں۔

CHAPTER

5 PHYSICAL STATES OF MATTER

Introduction:

The whole universe is made up of three things i.e. ~~matter, energy~~ and space.

Matter:

"Anything ~~that~~ has mass and occupy space is called matter." Matter exists in many states but the common most are:

- ~~Solid~~
- ~~Liquid~~
- ~~Gas~~
- Plasma
- ~~Liquid~~ crystals
- Super fluids
- Super solids and the
- Paramagnetic etc.

~~The common most states~~ of matter are solid, liquid and gas. All the three states of matter are ~~interconvertable~~ to one another.

$$\text{Solid} \underset{\text{Freezing}}{\overset{\text{Melting}}{\rightleftharpoons}} \text{Liquid} \underset{\text{Condensation}}{\overset{\text{Vaporization}}{\rightleftharpoons}} \text{Gas}$$

When the temperature of ~~solid~~ is increased it is converted into liquid and when the temperature of the liquid is increased it is then converted in-

to gaseous state. Similarly by cooling gases can be liquefied and by further cooling liquid can be freezed. Some substances by heating are directly converted into vapours state it is called sublimation. Similarly by super cooling gases, they are directly converted into solid state by passing the liquid state.

Q1: Define gaseous state. Write down the characteristic properties of gases.

Ans. Gaseous State:

Definition: "The highest energy state of matter having no definite shape and no definite volume is called gaseous state."

In gases the molecules are far away from each others. The intermolecular attractive forces are very weak. The molecules can move freely in all directions. Gases occupy the whole space available to them.

TYPICAL PROPERTIES:

(Malakand 2018, Peshawar 2019)

1. **Indefinite Volume:**

The gas molecules possess high kinetic energy and thus can move freely. They occupy all the available space and therefore have no definite volume. Gases can be expanded and compressed.

2. **Indefinite Shape:**

Gases have no definite shape and adapt (اختیار کرنا) the shape of the container in which it is kept.

3· **Diffusion:**

"The random (بے ترتیب) mixing of two different gas molecules in order to form a homogeneous mixture is called diffusion·" (OR)

"The spontaneous (خود بخود) mixing of the molecules of different gases to form a homogeneous mixture by random motion of collision of the molecules is called diffusion·"

Rate of diffusion is inversely proportional to the mass / density of the gas molecules· Lower the molecular mass of the gas molecule faster will be the rate of diffusion and vice versa·

Example: When a gas having characteristic smell is released at one corner of the room, soon its smell will spread in the whole room· Spreading of fragrance (خوشبو) molecules from a high concentration region to lower concentration region in a garden·

4· **Effusion:**

"The escape (نکلنا) of one kind of gas molecules one by one from the container through a hole [hole size is equal to molecular size] in the wall of the container is called effusion·"

We can smell the onions even when the bag is tightly sealed, due to effusion· A gas filled balloon floating up in the room comes down after a day or two due to effusion·

5· **Pressure:** (Kohat 2019)

"Force per unit area is called pressure·" Mathe-

matically it is represented by $P = F/A$. Gas molecules are in continuous state of motion. They collide with each others as well as with the walls of the container. The SI unit of force is Newton and that of area is m^2 so the SI unit of pressure is $N \cdot m^{-2}$ [Newton per meter square]. Nm^{-2} is also called Pascal (Pa). Its bigger form is kilopascal (KPa). At sea level and at $0C^\circ$ the atmospheric pressure is equal to 76cm of mercury, it is termed as one atmospheric pressure.

1 atm Pressure: The pressure exerted (ڈالنا) by 76cm long mercury column upon $1cm^2$ area at sea level at $0C^\circ$ is called 1atm pressure.

1 atm pressure = 76cm of Hg
= 76mm of Hg
= 760 torrs
= $101325 Nm^{-2}$
= 101325 Pascals
= 101.325 kilopascals
= 14.7 psi (pound per sq.inch)

6. **Compressibility:** (Bannu 2019)

Gases can be compressed by applying external pressure. Gases are highly compressible. This is because gas molecules have large empty spaces (خالی جگہ). When pressure is applied on the gases, distance between molecules decreases as a result volume also decreases. Compressibility of gases can be defined as "the change in volume per unit

change in pressure."

7. Mobility:

As the gas molecules have weak intermolecular attractive forces so gas molecules are in a state of constant/continuous random motion. They can move from one place to another place. Due to mobility property, gases can be transported through pipes over long distances.

8. Density:

"Mass per unit volume is called density."

$d = m/v$

It is clear from the above formula that density is inversely proportional to its volume. As gases have large volumes so they have low densities. Gases have low densities as compared to solids and liquids. At 0C° and 1-atm pressure, density of gaseous;

Oxygen = $0.00142 g/cm^3$

Density of liquid oxygen at -103C°

$= 1.149 g/cm^3$

Density of solid oxygen at -252C°

$= 1.426 g/cm^3$

9. Liquefaction:

Gases can be liquefied by increasing external pressure and decreasing temperature.

10. Gases expand on decreasing external pressure and also by heating.

Q2: State and explain Boyle's law. (BISE Malakand 2019, Swat 2019)

- **Ans.** Robert Boyle in 1762 gave a relationship between the volume of a fixed mass of a gas and external pressure at constant temperature.


Robert Boyle

Statement:

"The volume of the given mass of a gas is inversely proportional to the external applied pressure at constant temperature." It means that volume of a given mass of a gas decreases with the increase in external pressure.

Mathematical form:

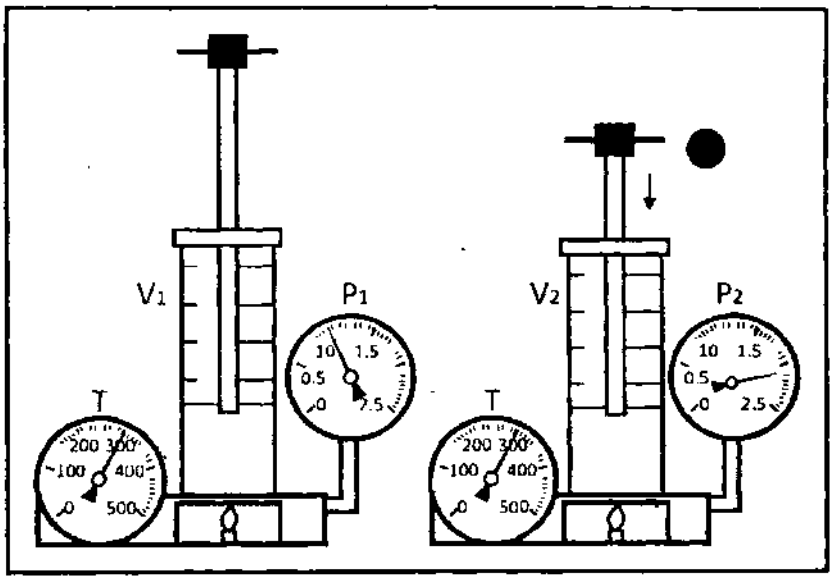
$$V \propto \frac{1}{P} \qquad [T = \text{constant}]$$

$$V = K_b \cdot \frac{1}{P} \Rightarrow PV = K_b \text{ ——— (1)}$$

Where "K_b" is called constant for Boyle's law. Where "K_b" is called constant for proportionality. From the above equation it is clear that product of pressure and volume is a constant quantity.

Experimental Verification:

Take a gas in a cylinder having moveable piston. Let its initial volume is (V_1) and initial external pressure upon it is (P_1). When external pressure is increased to (P_2), its volume will be reduced to (V_2).



Let initial volume = $V_1 = 2dm^3$

Let initial pressure = $P_1 = 2atm$

Let final volume = $V_2 = 1dm^3$

Let final pressure = $P_2 = 4atm$

By using and putting values in Boyle's equation, we get,

$$PV = K_b$$

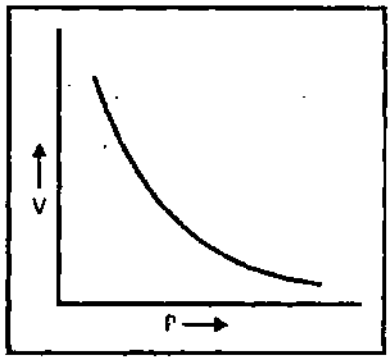
$$P_1V_1 = 2atm \cdot 2dm^3 = 4atm \cdot dm^3$$

$$P_2V_2 = 4atm \cdot 1dm^3 = 4atm \cdot dm^3$$

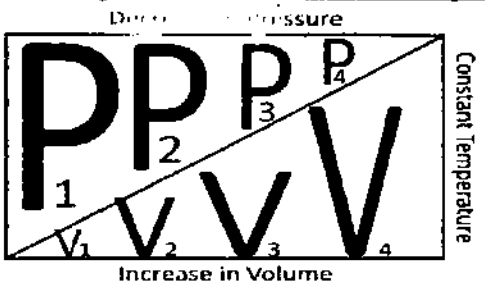
Thus $P_1V_1 = P_2V_2$ ..... Boyle's equation.

Graphical Representation:

When pressure is plotted against volume, a curve is obtained. As the temperature remains constant so this graph is also called isothermic graph.



Diagrammatic Representation of Boyle's Law:



EXAMPLE 5·1: A 530dm³ sample of hydrogen gas was collected in a container at 800mm of Hg pressure, at room temperature. What volume will the gas occupy at 400mm of Hg?

Solution:

Initial volume (V_1) = 530dm³

Initial pressure (P_1) = 800mmHg

Final volume (V_2) = ?

Final pressure (P_2) = 400mmHg

Applying Boyle's equation

$P_1V_1 = P_2V_2$ (OR)

$$V_2 = \frac{P_1V_1}{P_2}$$

$$V_2 = \frac{800\,\cancel{mm}Hg \times 530dm^3}{400\,\cancel{mm}Hg} = (1060dm^3)$$

PRACTICE PROBLEM 5·1:
Calculate the initial volume of a sample of gas at 1·20 atm. If its volume is changed to 70·4cm³ as its pressure is changed to 3atm at constant temperature.

Solution:

Initial volume = V_1 = ?

Initial pressure = $P_1 = 1{\cdot}20atm$
Final volume = $V_2 = 70{\cdot}4cm^3$
Final pressure = $P_2 = 3atm$

Using Boyle's equation,

$$P_1V_1 = P_2V_2$$

$$V_1 = \frac{P_2V_2}{P_1}$$

$$V_1 = \frac{3\,\cancel{atm} \times 70{\cdot}4cm^3}{1{\cdot}20\,\cancel{atm}}$$

$$\boxed{V_1 = 176cm^3}$$

Q3: State and explain Charles law.
(Peshawar 2018, Mardan 2018, Abbottabad 2019, Swat 2019)

Ans. In 1787, French physicist Jacques Charles observed relationship between volume of the given mass of a gas and temperature at constant external pressure.

Statement:

"The volume of the given mass of a gas is directly proportional to the absolute temperature at constant external pressure."

Mathematical Form:

$$V \propto T \quad [P = constant]$$

$$V = K_cT$$

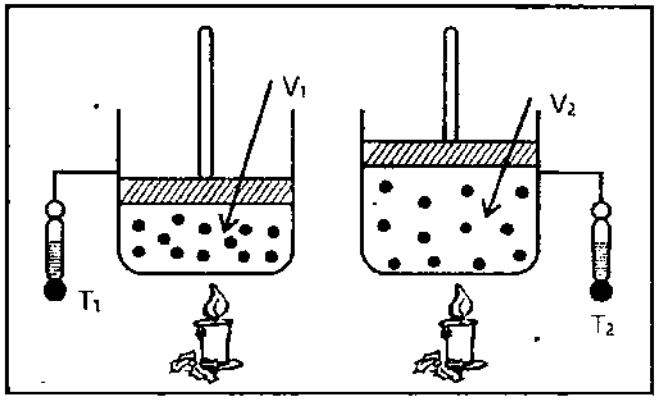
$$\frac{V}{T} = K_c \quad \text{_____(1)}$$

Where K_c is called proportionality constant. K_c = constant of Charles law. The above equation 1 shows that the ratio between volume to temper-

ature remains constant.

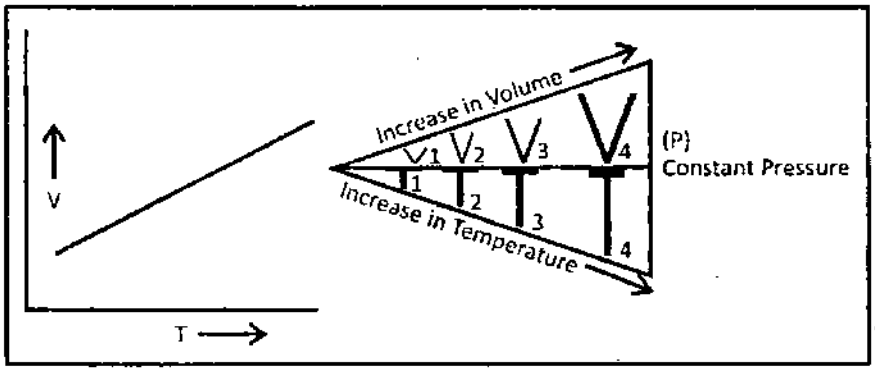
Experimental Verification:

Consider a gas is enclosed in a cylinder, fitted with a moveable and frictionless piston at constant external pressure. Let its initial volume is "V_1" at initial temperature "T_1". When the gas is heated, kinetic energy of its molecules increases. As a result the piston moves up and hence volume of the gas increases. Let its final volume is "V_2" at final temperature "T_2". The ratio between volume to temperature will remains constant. This relationship can be written as:



$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \longrightarrow \text{[Charles equation]}$$

Graphical and Diagrammatic Representation:



When volume is plotted against temperature, a straight line is obtained. As a general rule, when there is direct relationship between two variables is straight line graph is obtained.

SCIENTIFIC INFORMATIONS

Absolute temperature [as given in the statement of Charles law] means temperature on Kelvin scale. Each temperature on the absolute scale [Kelvin scale] is 273 times [units] greater than the same temperature on the Celsius scale. As $0C^{\circ} = 273K$.

Dear Students!

Whenever the temperature is given on centigrade scale, convert it into Kelvin scale by this formula: $[K = C^{\circ} + 273]$

EXAMPLE 5.2: If $3dm^3$ of air is heated from 300K to 400K at constant pressure, then what is the volume of the gas at higher temperature?

Solution:

Initial volume = $V_1 = 3dm^3$

Initial temperature = $T_1 = 300K$

Final temperature = $T_2 = 400K$

Final volume = $V_2 = ?$

Applying Charles equation

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

(or) $$V_2 = \frac{V_1 \cdot T_2}{T_1}$$

$$V_2 = \frac{3dm^3 \cdot 400K}{300K} = [4dm^3]$$

LIQUID STATE:

Liquid state is the state of matter in which intermolecular attractive forces are stronger than gases and weaker than solids. These forces of attraction are strong enough (ﷺ) to hold the molecules together but not so strong to stop the molecular motions. Liquid molecules have kinetic energy. They move randomly. A liquid therefore possess a fixed volume but no definite shape. The surface of a liquid is always leveled.

Q4: Define liquid state. Write down some general properties of liquids.

Ans. **Liquid State:**

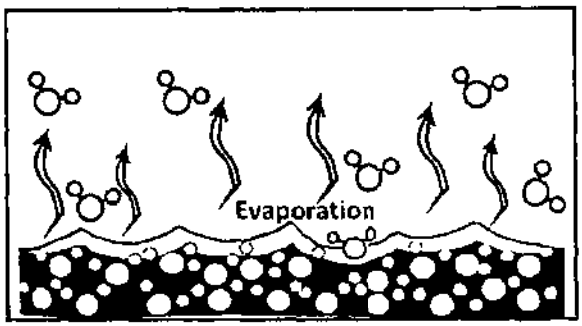
Definition: "The medium [intermediate] energy state of matter having definite volume and indefinite shape is called liquid state." Some of the general properties of liquids are:

1. Liquids have definite volume and indefinite shape. Liquids adapt the shape of the container in which it is kept. Liquids do not fill the whole container so they have a definite volume.
2. Liquids have the property of fluidity.
3. Liquids can diffuses into each other.
4. Liquids are soft.
5. Liquids are almost incompressible.
6. In liquids, the molecular motion is random.

Q5: Define and explain evaporation. What factors affect the rate of evaporation?

Ans. Evaporation: (Bannu 2019)

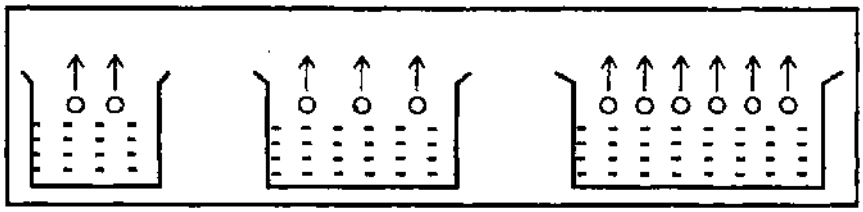
Definition: "The spontaneous / automatic conversion of a liquid into its vapours state is called evaporation."



The molecules of liquids move with different kinetic energies. The molecules having higher kinetic energies, move faster and overcome (قابو پانا) the intermolecular attractive forces. These molecules leave the surface of the liquid and changes into its vapours state. Evaporation occurs at all temperatures even at 0C°. Evaporation causes cooling. When the molecules of higher kinetic energies are converted into the vapours state and escape into the atmosphere, the remaining liquid becomes cool.

Factors Affecting Evaporation:

(a) Surface Area (سطحی رقبہ): As evaporation is a surface phenomenon. The process of evaporation takes place from the surface. It means that larger the surface area higher will be the rate of evaporation and vice versa (اس کے برعکس).



(b) Temperature: The rate of evaporation increases with increase in temperature. At high temperature, the molecules have high kinetic energy and velocity so they break the intermolecular attractive forces. Hence rate of evaporation increases with increase in temperature. For example, wet clothes become dry more quickly in summer as compared to winter.

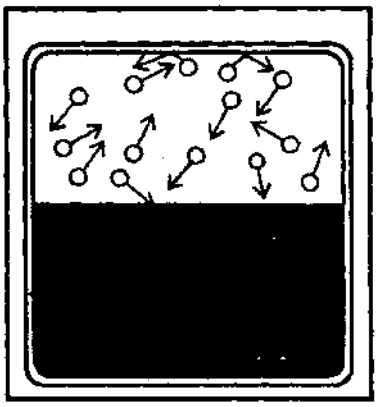
(c) Intermolecular Attractive Forces: Stronger the intermolecular attractive forces among liquid molecules, lower will be the rate of evaporation. Similarly weaker the intermolecular attractive forces higher will be the rate of evaporation. Different liquids have different rates of evaporation at the same temperature, because the intermolecular attractive forces are different in different liquids. For example, petrol and Alcohol evaporate quickly than water.

Q6: Define and explain vapours pressure. What factors affect vapours pressure?

Ans. *Vapours Pressure:* (Kohat 2019)

Definition: "The pressure exerted by vapours upon its liquid state at equilibrium state at a given temperature is called vapour pressure." Vapours

pressure does not depend upon the amount of liquid and surface area.



Explanation:

Consider a liquid is taken in a closed container. Some of the molecules will evaporate and will be accumulated above the surface of the liquid. With the passage of time the number of vapours increases. At the same time some vapours will condense back into the liquid state. The two process i.e. evaporation and condensation will continue until the rate of evaporation and condensation becomes equal. Thus a dynamic equilibrium is established.

Equilibrium State:

"The state at which rate of evaporation becomes equal to the rate of condensation is called equilibrium state."

Equilibrium : Rate of evaporation = Rate of condensation

Factors Affecting Vapours Pressure:

1. **Nature of Liquid:** By nature liquids are of two types, more volatile and less volatile liquids. The vapours pressure of liquids depends upon the nature of liquids. Polar liquids have lower vapours pressure than non-polar liquids, at the same temperature. Water has less vapours pressure than Acetone at the same temperature.

2. **Intermolecular Attractive Forces:** Stronger the intermolecular attractive forces among liquid molecules, lower will be the rate of evaporation and thus lower will be the vapours pressure. Similarly weaker the intermolecular attractive forces, higher will be the vapours pressure. For example, at 25C°;

Vapours pressure of water = 24mmHg

Vapours pressure of Ethyl Alcohol = 50mmHg

3. **Size of Molecules:** Those liquids composed of small sized molecules evaporate easily as compared to those liquids which are composed of large sized molecules. For example, pentane [C_5H_{12}] has small sized molecules than decane [$C_{10}H_{22}$], therefore pentane evaporate easily and exert more vapours pressure than decane at the same temperature.

Vapours pressure of some liquids at 25C°:

- Chloroform [$CHCl_3$]: 170mmHg
- Carbon tetrachloride [CCl_4]: 87mmHg
- Water [H_2O]: 24mmHg
- Glycerol [$C_3H_8O_3$]: 0.00016mmHg

4. **Temperature:** Vapours pressure of liquids increase with increase in temperature and decreases with decrease in temperature. Increase in temperature breaks the intermolecular attractive forces. For example,

Vapours pressure of water at 0C° = 4.5mmHg
Vapours pressure of water at 25C° = 24mmHg
Vapours pressure of water at 100C° = 760mmHg

Q7: Define boiling and boiling point. What factors affect the boiling point of liquids?

Ans. **Boiling:** (Mardan 2018)

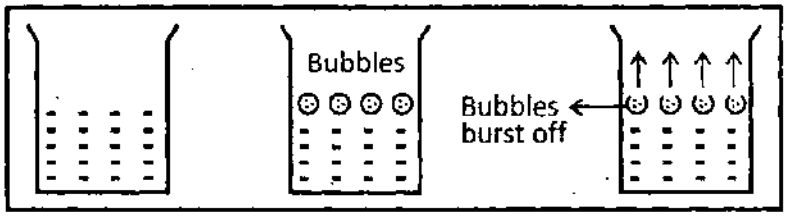
Definition: "The process of conversion of a liquid into its vapours when the vapours pressure becomes equal to external pressure is called boiling."

Boiling Point:

"The temperature at which the vapours pressure of a liquid becomes equal to external pressure is called boiling point." The boiling point of a liquid under normal pressure of 1-atm is called normal boiling point. The normal boiling point of water is 100C°.

Explanation:

When a liquid is heated, small bubbles are formed inside it. The vapours pressure inside the bubbles increases till it becomes equal to the atmospheric pressure on the top of the liquid. At this stage the bubbles burst off (ٹوٹ) and boiling starts. At the boiling point kinetic energy of the molecules of the liquid becomes maximum. At this point any further heating will not increase the temperature. This heat will be used to break the intermolecular attractive forces and convert the liquid into vapours. This is the reason that why temperature of the liquid remains constant at its boiling point.



Factors Affecting Boiling Point:

2. *Intermolecular Attractive Forces:* Liquids having strong intermolecular attractive forces among their molecules have high boiling point values as compared to those liquids having weak intermolecular attractive forces. For example,

Boiling point of water = 100C°

Boiling point of diethyl ether = 34.5C°

2. *External Pressure:* Boiling point of liquids increases with increase in external pressure and decreases with decrease in external pressure. At high altitude [hilly areas], the boiling point of a liquid will be less because the external pressure is lower. Therefore water boils at lower temperature than 100C° because the external atmospheric pressure is less than 1-atm or 760mmHg.

When external pressure = 4.5mmHg,

B.P of water = 0C°

When external pressure = 24mmHg,

B.P of water = 25C°

When external pressure = 700mmHg,

B.P of water = 98C°

When external pressure = 760mmHg,

B.P of water = 100C°

When external pressure = 1489mmHg,
B·P of water = 120C°
At Murree hills boiling point of water = 98C°
At Mount Everest boiling point of water = 72C°

Boiling points of some liquids are given below:
Boiling point of acetic acid [CH_3COOH] = 118·1C°
Boiling point of water [H_2O] = 100C°
Boiling point of benzene [C_6H_6] = 80·2C°
Boiling point of ethyl alcohol [$C_2H_5O_4$] = 78·4C°
Boiling point of carbon tetrachloride [CCl_4] = 61·2C°
Boiling point of chloroform [$CHCl_3$] = 76·8C°

Q8: Explain the following properties of liquids, freezing point, diffusion, mobility and density·

Ans· **Freezing Point [F·P]:**

Definition: "The temperature at which a liquid and its solid state have the same vapours pressure is called freezing point·" (OR)
"The temperature at which the liquid and solid state exists in equilibrium state is called freezing point of that liquid·"

Explanation:
When a liquid is cooled, the kinetic energies of the liquid molecules decreases, so the vapours pressure of the liquids also decreases· By further decreasing the temperature, the vapours pressure of the liquid state becomes equal to the vapours pressure of the solid state and liquid is converted into its solid state· It is to be noted that there

will be still some liquid molecules in equilibrium with solid state.

The freezing point of pure water = 0C°

$$H_2O_{(l)} \underset{}{\overset{0C°}{\rightleftharpoons}} H_2O_{(s)}$$

Freezing points of some liquids are given below:

Freezing point of ethanol = -114.7C°
Freezing point of chloroform = -63.5C°
Freezing point of water = 0C°
Freezing point of benzene = 5.5C°
Freezing point of acetic acid = 17C°
Freezing point of phenol = 43C°

DIFFUSION:

Miscible [mixable] liquids have the property of diffusion. They can diffuse into each others. The rate of diffusion of liquids is slower than the rate of diffusion of gases. For example, if a drop of ink is added into glass of water, the ink will spread slowly throughout the water. The ink molecules fill the gapes present among water molecules. The rate of diffusion increases with increase in temperature. The increase in temperature, increase the kinetic energy of liquid molecules so the rate of diffusion increases.

MOBILITY:

The kinetic theory of matter [particle theory], says that liquids consist of molecules which are constantly moving or in a state of constant random motion. This mobility of molecules depends

upon the energy of molecules. Higher the kinetic energy, the higher will be the mobility of molecules and vice versa. For example, when we increase the temperature [K.E] of liquids, the mobility [fluidity] of liquids increases.

DENSITY:

Density is defined as "mass per unit volume". Liquids have higher densities than gases and lower than solids. It is because, the molecules are close to each other in liquids as compared to gases. Liquid molecules have strong intermolecular attractive forces than gases, hence they can't expand and have a fixed volume.

Densities of Various Liquids:

S.No.	Liquid	Density (g/cm^3)	Temperature (C°)
1.	Acetone	0.792	20
2.	Ethyl alcohol	0.791	20
3.	Methyl alcohol	0.810	20
4.	Olive oil	0.918	15
5.	Castor oil	0.969	15
6.	Linseed oil	0.942	15
7.	Water	1.00	4

SOLID STATE:

Definition: "The state of matter having definite shape and volume is called solid state."

➢ The particles in solids are closely packed together. The attractive forces are very strong.

- The particles can only vibrate at their positions.
- Particles can't leave their own places.
- Diffusion of solid into solid is not possible.
- Solids are characterized by their hardness, rigidity, definite shape and volume.

Q8: Explain some typical properties of solids.

Ans. 1. **Definite Shape and Volume:**

Solids have strong intermolecular attractive forces so they have definite shapes and volume.

2. **Melting Point:**

We know that in solids the particles are not free to move. When a solid is heated, the kinetic energy of molecules increases and the particles of solids vibrate with higher speed. When the energy is continuously supplied, a stage is reached at which the particles leave their mean positions and start moving freely.

"The temperature at which the solid starts melting and exist in dynamic equilibrium with liquid state is called melting point."

At melting point, temperature does not change and remains constant until the whole solid is converted into the liquid state. Melting point of solid depends upon the strength of intermolecular attractive forces.

$$\text{Solid} \underset{\text{Freezing point}}{\overset{\text{Melting point}}{\rightleftharpoons}} \text{Liquid}$$

3. **Rigidity:**

The particles in solids are fixed and closely

packed. The particles in solids neither move nor slide over their mean positions. Therefore, the solids are rigid in their structures. The solid resist the deforming force due to hardness and strong intermolecular attractive force.

4. **Density:** (Swat 2019)

Density means mass per unit volume. ($d = m/v$)

Solids are denser than liquids and gases. In solids, the particles are closely packed and have no empty spaces between the particles. Their mass per unit volume is greater. Therefore they have higher densities as compared to liquids and gases.

SCIENTIFIC INFORMATIONS

Comparison of Properties of Solids, Liquids and Gases:

S #	Properties	Solids	Liquids	Gases
1.	Mass	Definite	Definite	Definite
2.	Shape	Definite	Acquires the shape of the container	Acquires the shape of the container
3.	Volume	Definite	Definite	Indefinite
4.	Compressibility	Not possible	Almost negligible	Highly compressible
5.	Fluidity	Not possible	Can flow	Can flow

6.	Rigidity	Highly rigid	Less rigid	Not rigid
7.	Diffusion	Slow	Fast	Very fast
8.	Space between particles	Most closely packed	Less closely packed	Least closely packed
9.	Intermolecular force	Strongest	Slightly weaker than in solids	Negligible

Q10: Explain types of solids.

Ans. Solids can be classified into two types. This classification is based on the arrangement of particles. These are amorphous solids and crystalline solids.

1. **Amorphous Solids:** (Mardan 2019)

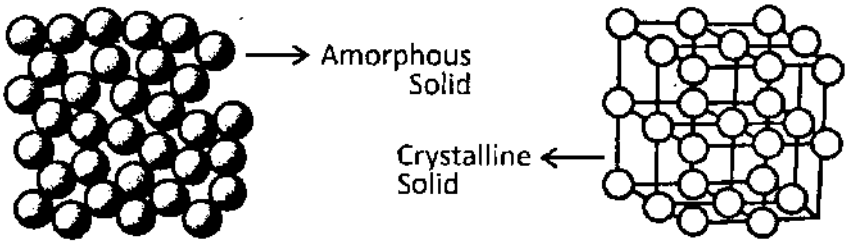
The word amorphous means shapeless or formless matter.. "The type of solids in which the particles are not regularly / properly arranged in three dimensions are called amorphous solids." These are also called powdered solids. Its examples are flour (آٹا), glass, wax, plastic, rubber, cotton and candy etc. They are hard like true solids but do not have sharp melting point. They melt over a long range of temperature.

2. **Crystalline Solids:** (Kohat 2019)

The solids in which particles [atoms, ions, molecules] are arranged in regular three dimensional pattern are called crystalline solids." These are

also called true solids. They have definite surfaces or faces. Each face has definite angle with the other face. Pure crystalline solids have sharp meting points. Sharp melting point is the temperature at which all the particles of a substance get released from their respective positions at the same time.

Examples are sodium chloride [NaCl], CaCO3



SOCIETY, TECHNOLOGY AND SCIENCE

Meat or fish preserved or cured with salt. Salting with sodium chloride [ordinary table salt] is the primary ingredient (ز) of preserving meat. Salt helps in creating an environment where bacteria cannot grow and removing water out of cells through osmosis. Concentrations of salt upto 20% are required to kill most species of unwanted bacteria.

Q11: Define allotropes and allotropy. Explain the allotropes of carbon.

Ans. Allotropes and Allotropy:

(Malakand 2018, Mardan 2018, Peshawar 2019, Abbottabad 2019)

Definition: *"Various forms of the same element having the same chemical properties but different physical properties are called allotropes and this phenomenon is called allotropy."*

Allotropes have the same chemical properties because they have the same number of electrons in the valence shell. The allotropy of an element is due to the following reasons:

1. *The existence of an element in more than one physical state/form, such as carbon [charcoal, soot, diamond, graphite].*
2. *The existence of two or more kinds of molecules of an element. In this case each molecule has different number of atoms, such as allotropes of oxygen are oxygen molecule [O_2] and ozone [O_3].*
3. *Different arrangements of two or more atoms or molecules in crystals of the element. For example, sulphur shows allotropy [monoclinic and orthorhombic forms] due to different arrangement of molecules "S_8" in the crystals.*
   - *Carbon is found in the form of diamond in tetrahedral shape and graphite in hexagonal shape. They have different physical properties due to having different shapes.*
   - *The change in temperature also changes the arrangement of atoms in allotropes. With a change in temperature a new allotropic form is produced.*

Transition Temperature:

Definition: "The temperature at which two allotropic forms of an element co-exist in equilibrium with each other is called a transition temperature." (OR)

"The temperature above or below which only one allotropic form can exist is called transition temperature." For example,

$S_8 \underset{}{\overset{95.5C^\circ}{\rightleftharpoons}} S_8$

(Orthorhombic) (Monoclinic)

Gray tin $\overset{13.2^\circ C}{\rightleftharpoons}$ White tin

(Cubic) (tetragonal)

$KNO_3 \overset{128.5^\circ C}{\rightleftharpoons} KNO_3$

(Rombohedral) (Orthorhombic)

(Also called polymorphs)

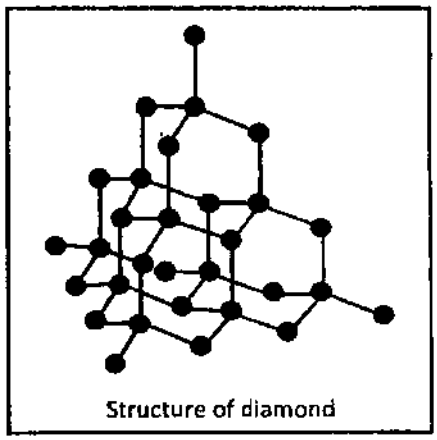
Allotropes of Carbon: (Mardan 2019)

Carbon exists in crystalline allotropic forms as well as non-crystalline / amorphous allotropic forms. Crystalline carbon exist in three allotropic forms namely, diamond, graphite and bucky balls. Carbon also exists in non-crystalliny / amorphous allotropic forms such as coal, coke, charcoal, lampblack etc.

(i) Structure of Diamond: (Peshawar 2019)

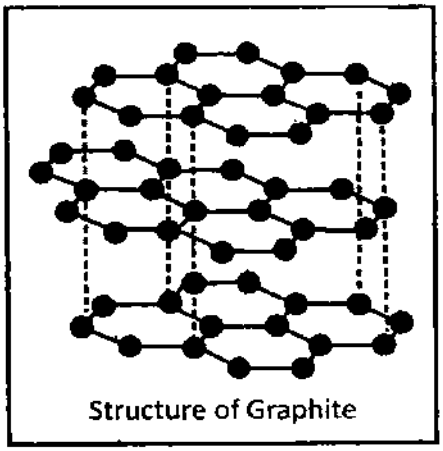
Diamond is the crystalline allotropic form of carbon. In diamond, carbon exists in cubic form. Each carbon atom is tetrahedrally bonded by four cova-

lent bonds with four other carbon atoms. Due to strong covalent bonds, diamond is very hard and has high melting point [3500C°]. Diamond is bad conductor of electricity because all the four valence electrons are used in the formation of covalent bonds and there is no free electron to move.


Structure of diamond

(ii) Structure of Graphite: [Graphite means to write]

In graphite carbon atoms are arranged hexagonally in the form of sheets. Each carbon atom is covalently bonded to three other carbon atoms. There is weak attractive force between the layers or sheets. Due to weak attraction, the sheets slide over each other, as a result graphite is soft lubricant. As each carbon is further attached to three carbon atoms and the 4th electron is free to move, so graphite is good conductor of electricity.

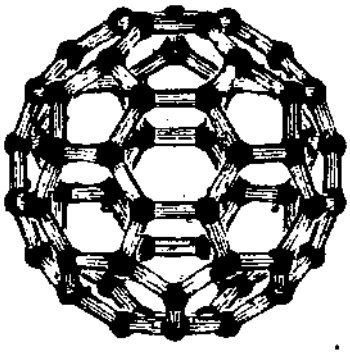

Structure of Graphite

(iii) Structure of Bucky Balls: (Kohat 2019)

Definition: "Molecules composed of even number

of carbon atoms, forming a hollow cage like fused polycyclic ring system having 12-pentagone and the remaining hexagons are called bucky balls."

Bucky ball is the 3rd crystalline allotropic form of carbon. It is recently discovered in 1985. Bucky balls consist of 20 - 100 carbon atoms. The atoms are arranged in a hollow cage like structure. The carbon atoms after linking with each other adopt (اپنا) the shape of a football. It is also called footballene. In bucky balls carbon atoms are joined together, making pentagonal, hexagonal or even heptagonal structures. Bucky balls are used as:



Structure of Bucky Ball

1. Semiconductors
2. Superconductors
3. Lubricants

Exercise

Choose the correct option:

1. The spontaneous mixing of particles is called:
   (a) Evaporation (b) Sublimation
   (c) Diffusion✓ (d) Boiling
2. Which statement for the particles of solids is not correct?
   (a) They move at great speed✓
   (b) They are arranged at regular pattern
   (c) There is a very little space between the particles.
   (d) Force of attraction between particles is strong
3. A liquid boils when its vapours pressure becomes equal to:
   (a) 760cm of Hg
   (b) 1 Pascal
   (c) 101·325 kilopascal✓
   (d) 0·1 atm
4. The vapours pressure of a liquid increases with the:
   (a) Increase of pressure
   (b) Increase of temperature✓
   (c) Increase of IMAF
   (d) Increase of polarity
5. Water normally boils at 100C° but is possible to boil at 50C°, which variable you would have to change to do this?
   (a) Increase external pressure
   (b) Decrease external pressure ✓

(c) Increase surface area
(d) Decrease surface area

6. The vapours pressure of a liquid in closed container depends upon:
(a) Amount of liquid
(b) Surface area of liquid
(c) Temperature✓
(b) Both (a) & (b)

7. At freezing point which one the following exist in dynamic equilibrium:
(a) Gas and solid
(b) Liquid and gas
(b) Liquid and solid✓
(d) All of these

8. Which one of the following is not an example of amorphous solid?
(a) Rubber (b) Glass
(c) Glucose✓ (d) Plastic

9. Ink spreads in water because of:
(a) Vapours pressure
(b) Expansion
(c) Diffusion✓
(d) Compressibility of water

10. What will be the pressure of a gas, if the volume of the gas at 2-atmospheres is increased from 1·5dm^3 to 3dm^3?
(a) 1-atmosphere✓ (b) 1·5 atmosphere
(c) 2-atmosphere (d) 2·5 atmosphere

Solution:

$V_1 = 1{\cdot}5dm^3$ $P_1V_1 = P_2V_2$

$P_1 = 2atm$ $P_2 = \frac{P_1V_1}{V_2}$

$V_2 = 3dm^3$ $P_2 = \frac{2atm \cdot 1{\cdot}5dm^3}{3dm^3} = \boxed{1\ atm}$

$P_2 = ?$

Numerical Questions

Solve the following numerical questions:

Q1: Calculate the final pressure of a sample of gas that is changed at constant temperature to $14{\cdot}3dm^3$ from $7{\cdot}55dm^3$ at 828 torr.

Solution:

Initial volume = $V_1 = 7{\cdot}55dm^3$

Initial pressure = $P_1 = 828$ torrs

Final volume = $V_2 = 14{\cdot}3dm^3$

Final pressure = $P_2 = ?$

Using Boyle's quation

$P_1V_1 = P_2V_2$

$P_2 = \frac{P_1V_1}{V_2}$

Putting the values

$$P_2 = \frac{828\ torrs \cdot 755\ \cancel{dm^3}}{14{\cdot}3\ \cancel{dm^3}} = [437{\cdot}16\ torrs]$$

Q2: Calculate the final volume at 302K of a 541dm³ sample of gas originally at 353K, if the pressure does not change.

Solution:

Initial volume = $V_1 = 541dm^3$

Initial temperature = $T_1 = 353K$

Final volume = $V_2 = ?$

Final temperature = $T_2 = 302K$

Using Charles equation

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad (OR)$$

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{541\ dm^3 \cdot 302\ K}{353\ K}$$

$$= \frac{163382}{353} = [462{\cdot}83\ dm^3]$$

Q3: Calculate the initial volume at 0C° of a sample of gas that is changed to 731cm³ by cooling to -14C° at constant pressure.

Solution:

Initial temperature = $T_1 = 0C° \rightarrow 273K$

Initial volume = $V_1 = ?$

Final volume = $V_2 = 731cm^3$

Final temperature = $T_2 = -14C° \Rightarrow 259K$

Using Charles equation

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_2 = \frac{V_2 \cdot T_1}{T_2}$$

$$V_2 = \frac{731cm^3 \cdot 273K}{259K} = [770{\cdot}513cm^3]$$

$K = C° + 273$
$K = -14 + 273$
$K = 259$

Q4: A sample of a gas at room temperature occupies 0·80dm³ at 1·5 atm. What will be its volume when the pressure of the gas is raised to 2·1atm?

Solution:

Initial volume = $V_1 = 0{\cdot}80dm^3$

Initial pressure = $P_1 = 1{\cdot}5$ atm

Final volume = $V_2 = ?$

Final pressure = $P_2 = 2{\cdot}1$ atm

Using Boyle's equation

$$P_1V_1 = P_2V_2 \quad (OR) \quad V_2 = \frac{P_1V_1}{P_2}$$

$$V_2 = \frac{1{\cdot}5atm \cdot 0{\cdot}80dm^3}{2{\cdot}1\ atm} \Rightarrow \left[V_2 = 0{\cdot}571\ dm^3\right]$$

Q5: Calculate the final volume at 319C° of a sample of a gas original 5·13dm³ at 171C°, if the pressure does not change.

Solution:

Initial volume = $V_1 = 5{\cdot}13dm^3$

Initial temperature = $T_1 = 171C° \Rightarrow 444K$

Final temperature = $T_2 = 319C° \Rightarrow 592K$

Final volume = $V_2 = ?$

Using Charles equation

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad (OR) \quad V_2 = \frac{V_1 \cdot T_2}{T_1}$$

$$V_2 = \frac{5{\cdot}13dm^3 \cdot 592\cancel{K}}{444\cancel{K}} = \left[6{\cdot}84\ dm^3\right]$$

Short Questions

Q1: Can you give reason why it takes longer time to cook at high altitude?

Reasons: We know that boiling point of a liquid is directly proportional to external pressure. At high altitude the external pressure is low, as a result water will boil at lower temperature than normal [100C°] and cooking will take longer time. The hot and high K.E molecules will escape from the container and cool molecules remains behind so more heat and longer time will be required for cooking.

Q2: Glass soften (نرم ہو) over a wide range of temperature. Ice melts at a specific temperature. Explain reason for this difference.

Ans. We know that pure crystalline substances have a sharp melting point. While amorphous solids melt over a wide range of temperature. So glass soften over a wide range of temperature because it is an amorphous solid and ice melts at a specific temperature [0C°] because it is a crystalline solid.

Q3: Explain why it happens that on a hot summer day, when there is sweat on the body of a person, one feels cool under fast moving fan?

Ans. Under sitting a fast moving fan, sweat molecules absorb heat from the body, goes to vapours state and hence lower the body temperature, so one can feel coolness. Under a fast mov-

ing fan, evaporation occurs rapidly as evaporation cause cooling so the person will feel cooling.

Q4: Why are the densities of gases lower than that of liquids?

Ans. We know that mass per unit volume is called density, $d = m/v$

It means that density and volume has inverse relationship when we take the same mass of a gas and liquid. As the gas occupy more space [volume] so its density will be lower to that of a liquid.

Density of oxygen gas = $0.00142 g/cm^3$

When it is converted into liquid state then its density becomes $1.149 g/cm^3$.

Q5: What is the relationship between atmospheric pressure and boiling point of a liquid?

Ans. The boiling point of a liquid has a direct relationship with external pressure. It means that higher the external pressure higher will be the boiling point and lower the external pressure lower will be the boiling point. For example, boiling point of water under 760mmHg pressure = 100C°

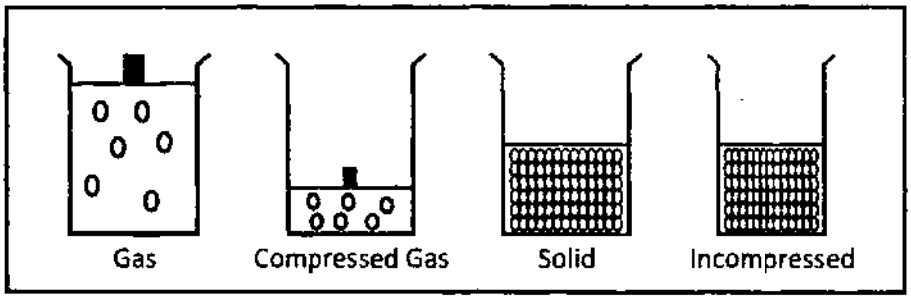
700mmHg pressure = 98C°

Q6: Why a gas is compressible but a solid is not compressible? Give reason.

Ans. Gases are highly compressible as compared to

solids because there are large empty spaces among gas molecules. When external pressure is applied the gas molecules come closer, empty spaces are reduced, volume decreases and hence the gas is said to be compressed.

On the other hand, solid molecules touches the surfaces of each other, there are no empty spaces, hence cannot be compressed by applying external pressure.



Long Questions

Q1: Define Boyle's law and verify it experimentally.

Ans. Please see question # 2.

Q2: Differentiate between (a) evaporation and boiling point (b) effusion and diffusion (c) Condensation and Evaporation

Ans. (a) **Evaporation and Boiling Point:**

Evaporation: "The spontaneous conversion of a liquid into its vapours is known as evaporation. It can occur at $0C^{\circ}$.

Boiling Point: "The temperature at which the vapours pressure of a liquid becomes equal to external pressure is called boiling point. Evaporation

of water can take place at 0C° but its boiling point is 100C° under 1-atm pressure.

(b) Effusion and Diffusion:

1. Diffusion is the random mixing of two different gas molecules while effusion is the escape of one kind of gas molecules one by one through a hole in the wall of the container.
2. Diffusion takes place among different gas molecules while effusion takes place only in the same gas [pure gas] molecules.
3. There is collision in case of diffusion while no collision occurs in case of effusion.

(c) Condensation and Evaporation:

Evaporation is the conversion of a liquid into its vapours while condensation is the conversion of vapours back into its liquid state. During evaporation molecules of liquids gain heat while during condensation heat is lost.

Q3: Define the term allotropy with the help of examples. Explain the three allotropic forms of carbon in detail.

Ans. Please see question # 11.

Q4: What are solids? Differentiate between amorphous and crystalline solids.

Ans. See question # 10.

Q5: Define Charles law and verify its graphically and diagrammatically.

Ans. Please see question # 3.

❑❑❑

CHAPTER 6

SOLUTIONS

Q1: Define the following terms. Give examples where needed. Solution, aqueous solution, non-aqueous solution solute, solvent, saturated solution, unsaturated solution, super saturated solution, dilute solution and concentrated solution

Ans. **Solution:** (Mardan 2017)

"A homogeneous mixture of two or more than two substances is called a solution." For example; when sodium chloride salt is dissolved in water, a solution is formed. A solution which is made up of two components is called a binary solution. For example sucrose (ﷺ) dissolved in water. A solution which is made up of three components is called ternary solution. For example; when sucrose and NaCl both are dissolved in water a ternary solution is formed. Generally a solution has two components, i.e. solute and solvent.

Solute:

"The component present in smaller amount is called a solute." It dissolves in solvent.

Solvent:

"The component which is present in greater

amount than the other one is called a solvent." It dissolves the solute. For example; sugar solution is made by dissolving sugar in water. In this solution sugar is solute and water is solvent.

Aqueous Solution:

"A solution in which water is used as a solvent is called aqueous solution." The solution of sodium chloride in water is the example of aqueous solution.

Non-Aqueous Solution:

"The solution in which solvent other than water is used is called a non-aqueous solution." For example; solution of iodine in carbon tetrachloride [CCl_4] solvent is called non-aqueous solution.

Unsaturated Solution:

"A solution which can dissolve more / further solute at a given temperature is called an unsaturated solution."

Example: If we dissolve a small amount of sugar in water, this solution still has the capacity (صلاحیت) to dissolve more solute, so it is termed as unsaturated solution.

Saturated Solution:

"The solution which cannot dissolve more solute at a given temperature is called a saturated solution." For example; if we add sugar continuously to water in a glass with constant stirring, a stage is reached when the further amount of solute will not dissolve in it and will settle down at the bottom, this is called saturated solution.

Super Saturated Solution:

"A solution which cannot dissolve more solute at high temperature is called super saturated solution." For example; when a saturated solution is heated, it has the capacity to dissolve more amount of solute. A stage will reach when the further amount of solute will settle down and no more dissolution will takes place even at high temperature, such a solution is called super saturated solution.

Identification of a Solution as Unsaturated, Saturated and Super Saturated:

Procedure:

When a crystal of already dissolved solute is added to each of the three solutions. If the crystals dissolves, the solution is unsaturated. If it remains un-dissolved, it is saturated solution. If some excess of the dissolved solute deposits on the crystal, then it is super saturated solution.

Concentration of Solution:

Concentration is the amount of a solute in a solution. "The ratio of the amount of solute in a given amount of solvent or solution is called concentration of solution." The larger the amount of solute present in a solution, the higher will be the concentration.

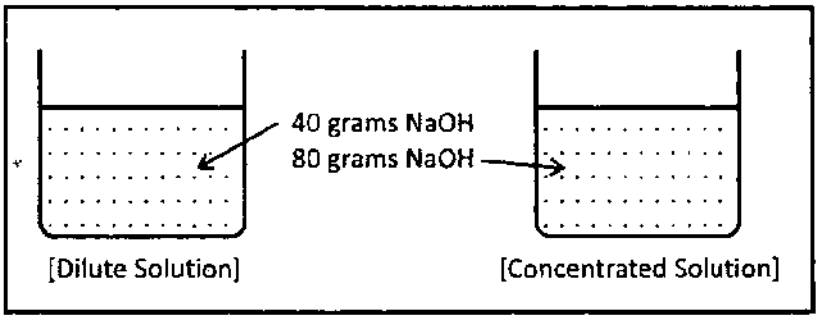
Dilute Solution:

"A solution which contains small amount of solute in the given amount of solvent / solution is

called dilute solution."

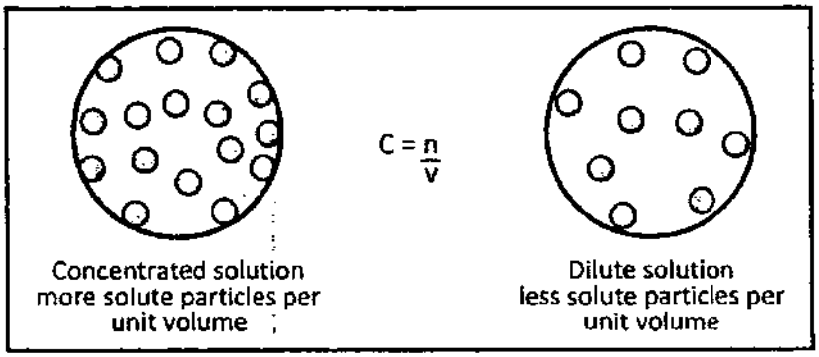
Concentrated Solution:

"A solution which contain large amount of solute in the given amount of solvent/solution is called a concentrated solution."



Standard Solution:

"A solution of known concentration is called a standard solution."



Q2: Explain the following concentration units:
(1) Percent composition (2) Molarity

Ans. 1. **PERCENT COMPOSITION:**

Definition: "It is the number of parts of solute present in 100 parts of solution." (OR) The fraction of a solute in a solution multiplied by 100. The percentage composition of a solution

can be expressed by four ways.

(i) Percentage Mass by Mass/Mass-Mass Relationship: [% m/m]

It is the number of grams by mass of solute present in 100 grams by mass of a solution. For example; 10% solution of sugar by mass means, 10 grams of sugar in 90 grams of solvent, so that the solution weighs 100 grams.

$$\%\frac{mass}{mass} = \frac{mass\ of\ solute_{(g)}}{mass\ of\ solute_{(g)} + mass\ of\ solvent} \times 100$$

$$\%\frac{m}{m} = \frac{mass\ of\ solute}{mass\ of\ solution} \times 100$$

(ii) Percentage Mass by Volume [% m/v]:

It is the number of grams by mass of solute present in $100cm^3$ [100mL] of solution. For example; 10% solution of NaCl mass/ volume means, 10 grams of NaCl is dissolved in so much solvent to make $100cm^3$ total solution. In this case total mass of solution is not considered.

$$\%\frac{m}{v} = \frac{mass\ of\ solute_{(g)}}{volume\ of\ solution\ in\ cm^3} \times 100$$

(iii) Percentage Volume by Mass [% v/m]:

It is the volume in cm^3 of a solute dissolved in 100 grams of solution. For example; 10% solution of alcohol volume/mass means, $10cm^3$/ml of alcohol is dissolved in so much water so that the total mass of the solution is 100g. Here total volume of the solution is not considered.

$$\%\frac{v}{m} = \frac{\text{volume of solute } (cm^3)}{\text{mass of solution}_{(g)}} \times 100$$

(iv) Percentage Volume by Volume [% v/v]:
(Abbottabad 2019)

It is the volume in cm^3/ml of a solute dissolved per $100cm^3$ of solution. For example; 10% solution of alcohol by volume means, $10cm^3$ of alcohol in sufficient volume of solvent, so that the total volume of solution becomes $100cm^3$/ml.

$$\%\frac{v}{v} = \frac{\text{volume of solute } (cm^3)}{\text{volume of solution } (cm^3)} \times 100$$

2. MOLARITY (M):
(Mardan 2019, Swat 2019, Bannu 2019)

Molarity is another concentration unit. It is defined as; "the number of moles of solute dissolved per dm^3 [litre] of solution". It is represented by "M". mathematically:

$$M = \frac{\text{number of moles of solute}}{\text{volume of solution in } dm^3}$$

$$\text{As number of moles} = \frac{\text{mass of solute}}{\text{molar mass of solute}}$$

$$\text{Thus } M = \frac{\text{mass of solute}}{\text{molar mass of solute} \times \text{volume of solution in } dm^3}$$

EXAMPLE 6.1: Calculate the molarity of a solution containing 7.50 mole of $CaCO_3$ in enough water to make 1.50 dm^3 of solution.

Solution:

Using the formula

$$M = \frac{\text{number of moles of solute}}{\text{volume of solution in } dm^3}$$

$$M = \frac{7{\cdot}50\ mole}{1{\cdot}50\ dm^3} = \left[5\ mol{\cdot}dm^{-3}\right]$$

Q3: Explain problems involving the molarity of a solution. Give examples.

Ans. In order to find out the molarity of a solution we must know the molar mass of solute. For example; 1-molar solution of glucose [$C_6H_{12}O_6$] means, one mole [180 grams] of glucose per dm^3 of solution.

- 1-molar solution of sodium hydroxide [NaOH] contains one mole of NaOH [40 grams] in one dm^3 of solution.
- As the symbol for molarity is "M" and the concentration of 1-molar solution of sodium hydroxide is written as "1M" NaOH.

Preparation of 1-Molar NaOH Solution:

- One mole of NaOH has a mass of 40 grams. If 40 grams of NaOH is dissolved in enough water to make exactly $1dm^3$ of solution, the solution is now 1 molar solution.
- If 20 grams of NaOH [which is 0·5/ ½ mole] is dissolved in enough water to make one dm^3 solution, a 0·500M NaOH solution is produced. This relationship between molarity, moles and volume may be expressed in the following ways:

$$M = \frac{\text{amount of solute in grams}}{\text{molecular weight of solute x volume of solution in } dm^3}$$

$$M = \frac{40g}{40g \times 1dm^3} = \boxed{1 \text{ mole}}$$

$$\text{(or) } M = \frac{20g}{40g \times 1dm^3} = \boxed{0{\cdot}500 \text{ mole}}$$

If twice the molar mass of NaOH, i·e· 80g is dissolved in enough water to make $1dm^3$ of solution, a 2 molar solution is produced·

EXAMPLE 6·2: Calculate the molarity of $50cm^3$ of solution containing 7·50 grams of CH_3OH·

Solution:

We know that molarity is defined in terms of moles of solute and litres of solution· The given quantities can be converted to moles and litres respectively (بالترتیب)·

Molar mass of CH_3OH: 12 + 4 + 16 = 32g/mole

$$\text{Number of moles of } CH_3OH = \frac{\text{mass}}{\text{molar mass}}$$

$$n = \frac{7{\cdot}50\,g}{32\,g \cdot mol^{-1}} = (0{\cdot}2344 \text{ mole})$$

Converting cm^3 into dm^3: $\frac{50}{1000} = \left[0{\cdot}0500\ dm^3\right]$

To find out molarity, the formula used is:

$$M = \frac{\text{number of moles}}{\text{volume in } dm^3}$$

$$M = \frac{0{\cdot}2344 \text{ mol}}{0{\cdot}0500\ dm^3} = \left[4{\cdot}69M\right] \text{ or}$$

$$(4{\cdot}69 \text{ mol} \cdot dm^{-3})$$

EXAMPLE 6·3: 5·8 grams of NaCl is dissolved in water so as to make 500cm³ solution. Determine the molarity of the solution [atomic mass of Na = 23g, Cl = 35·5g]

Solution:

Mass of NaCl = 5·85 grams

Molar mass of NaCl = 23 + 35·5 = 58·5 g/mol

$$\text{Number of moles of NaCl} = \frac{5\cdot85\text{g}}{58\cdot5\text{g}\cdot\text{mol}^{-1}} = [0\cdot1 \text{ mole}]$$

Volume of solution i n cm^3 = 500cm^3

$$\text{Volume of solution in } dm^3 = \frac{500}{1000} = (0\cdot5\ dm^3)$$

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in } dm^3}$$

$$M = \frac{0\cdot1\ \text{mol}}{0\cdot5\ dm^3} = 0\cdot2\ \text{mol}\cdot dm^{-3} \text{ or } (0\cdot2M)$$

PRACTICE PROBLEM 6·1:

Calculate the molarity of 11·6cm^3 of solution containing 0·70 grams of $CaCl_2$:

Solution:

Volume of solution in cm^3 = 11·6cm^3

Volume of solution in dm^3 =

$$\frac{11\cdot6}{100} = \boxed{0\cdot116 dm^3}$$

Mass of solute [$CaCl_2$] = 0·70 grams

Molar mass of $CaCl_2$ $[40 + (35\cdot5 \times 2)]$

= 40 + 71 = 111 g/mol

$$\text{Number of moles (n)} = \frac{\text{mass}}{\text{molar mass}} = \frac{0\cdot70\text{g}}{111\text{g}\cdot\text{mol}^{-1}}$$

$= \boxed{0.0067 mol}$

$$Molarity\ (M) = \frac{number\ of\ moles}{volume\ in\ dm^3}$$

$$M = \frac{0.0067}{0.116} = \left[0.577\ mol \cdot dm^{-3}\right]$$

SCIENTIFIC INFORMATIONS

To dilute a stock solution, dilution equation is used, $M_1V_1 = M_2V_2$ where M_1 and V_1 are the molarity and volume of the concentrated stock solution and M_2 and V_2 are the molarity and volume of diluted solution you want to make.

EXAMPLE 6.4: What volume of water must be added to $85cm^3$ of 3.5M Na_2CO_3 to dilute it to 0.4M?

Solution:

$M_1 = 3.5M \qquad V_1 = 85cm^3$

$M_2 = 0.40M \qquad V_2 = ?$

Formula used

$$M_1V_1 = M_2V_2 \ (OR)\ M_2V_2 = M_1V_1$$

$$V_2 = \frac{M_1V_1}{M_2}$$

$$V_2 = \frac{3.5 \times 85}{0.41} = \left[725.60cm^3\right]$$

Volume of solution = 725.60 - 85 = $\left[640.60cm^3\right]$

So $640.60cm^3$ volume will be needed /added to get dilution.

Q4: Define solubility. What are the factors which affect solubility?

Ans. Solubility: "The amount of solute required to saturate 100 grams of solvent at a given temperature is called solubility." Different substances have different solubilities in the same amount of solvent at a specific temperature. For example, sodium nitrate [$NaNO_3$] is more soluble than silver chloride [AgCl] in water.

$$\text{Solubility} = \frac{\text{mass of solute}}{\text{mass of solvent}} \times 100$$

Factors Affecting Solubility: (Malakand 2018)

The following factors affect the solubility of a solute in a solvent:

1. Temperature
2. Pressure
3. Nature of solute
4. Nature of solvent

1. Nature of Solvent:

There is a general rule that like dissolves like. It means that solutes having similar structure and properties to the solvent molecules will be soluble in it. For example; sodium chloride is an ionic compound. It has greater solubility in a polar solvent like water but low solubility [insoluble] in non-polar solvent like benzene.

2. Nature of Solute:

Nature of solute also affects the solubility. If a solute is changed and the solvent remains the

same, the solubility of the solute also changes. For example; sodium chloride has high solubility in water and sugar has comparatively low solubility in water.

At 20C°, 100 grams of water dissolve =192g NH_4NO_3

At 20C°, 100 grams of water dissolve = 6·5g $HgCl_2$

The "general principle of solubility" is "like dissolve like". It means that

Polar solute + polar solvent = soluble

Ionic solute + polar solvent = soluble

Non-polar solute + non-polar solvent = soluble

Non-polar solute + polar solvent = insoluble

3. **Pressure:** (Kohat 2019)

Pressure has no effect on the solubility of solids and liquids. It is because solids and liquids are incompressible. Solubility of gases increases with increase in external pressure. For example in soda water bottles CO_2 gas is dissolved under 4-5 atmospheric pressure. When the lid (ڈھکن) is removed from these bottles, the gas comes out with effervescence [bubbles]. It is because in open market the external pressure is low [normal].

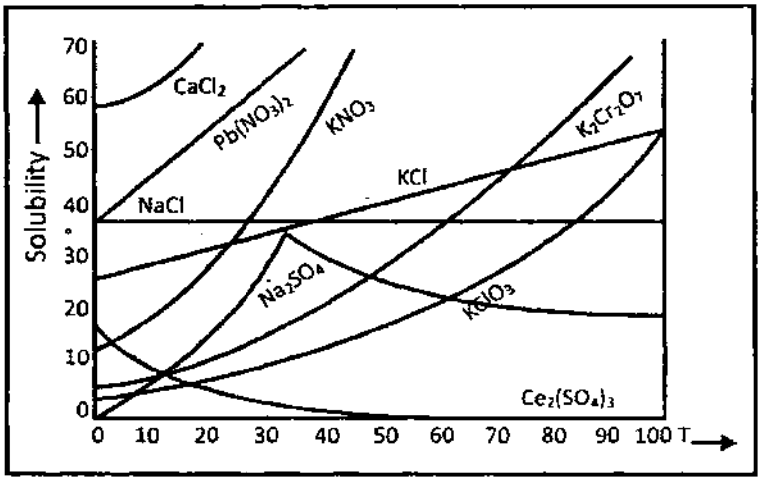
HENRY'S LAW

At constant temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas above it.

4. **Temperature:** (Kohat 2019)

Generally the solubility of solids in liquids increases with increase in temperature, but this not al-

ways happen. When a solute [salt] is added into a solvent, there are different possibilities with reference to effect of temperature.



i) The solubility of some solutes increases with rise in temperature. For example, the solubility of potassium nitrate [KNO_3], calcium chloride [$CaCl_2$] and lead nitrate.

ii) The solubility of some solutes decreases with increase in temperature. For example, $Ce_2(SO_4)_3$, Li_2CO_3 and CaO.

iii) The solubility of NaCl and KBr is not affected by increase or decrease in temperature and remains constant.

iv) There are some solids, whose solubility increases upto a certain temperature and then decreases on further increase in temperature. For example; sodium sulphate decahydrate ($Na_2SO_4 \cdot 10H_2O$). Its solubility increases upto 32.4C° and above 32.4C° its solubility de-

creases because it becomes anhydrous.

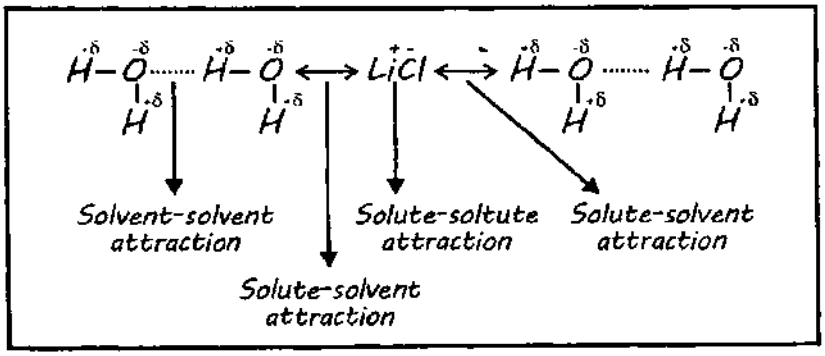
Q5: Explain solute – solvent interaction.
(Mardan 2017)

Ans. Solute-Solvent Interactions:

Lithium chloride is highly soluble in water but gasoline is not. On the other hand, gasoline mixes readily with benzene but lithium chloride does not. "Like dissolve like" is useful rule for predicting whether one substance will dissolve in another or not.

1. Dissolving Ionic Compounds in Polar Solvent:

The polarity of water molecules plays an important role in the formation of solutions of ionic compounds in water. The charged ends of water molecules attract the ions in the ionic compounds and surround them to keep them separate from the other ions in the solution. For example, if we add a few crystals of lithium chloride [LiCl] into a beaker of water. The water molecules come into contact with Li^+ and $\bar{C}l$ ions. The positive ends of water molecules are attracted by $\bar{C}l$ ions while the negative ends are attracted by Li^+ ions.



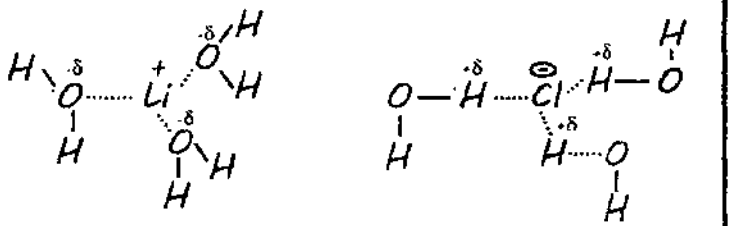
If the attraction between water molecules and solute ions is greater than the attraction between particles themselves [solute- solute attraction] then the solute will be dissolved otherwise no dissolution takes place.

Hydration:

"The process during which water molecules surround and interact with solute ions is called hydration."

Hydrated Ions:

"The ions which are surrounded by water molecules are called hydrated ions." As hydrated ions diffuse into the solution, other ions are exposed and are drawn away from the crystal surface by the solvent. The whole crystal gradually dissolves and hydrated ions become uniformly distributed in the solution.



Hydration process and hydrated Li & $\bar{C}l$ ions

2. **Dissolving Ionic Compounds in Non-Polar Solvents:**

Ionic compounds are generally not soluble in non-polar solvents such as carbon tetrachloride [CCl_4] and benzene [C_6H_6]. The non-polar solvent molecules do not attract the ions of the crystal

strongly enough to overcome the forces holding the crystal together.

Q6: Explain solutions of liquids in liquids.

Ans. Solutions of liquids in liquids are classified into three classes:

1. **Completely Miscible Liquids:**

Liquids which mix up with each other in all proportions are called completely miscible liquids. Examples are given below:

- Water and alcohol
- Ether and alcohol
- Benzene and alcohol

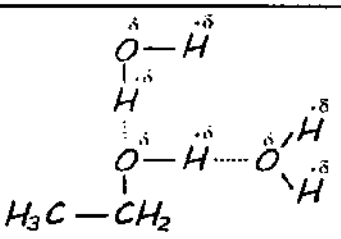
2. **Completely Immiscible Liquids:**

"Liquids which do not mixes at all (بالکل) are called completely immiscible liquids." Examples are given below:

- Water and phenol
- Water and ether
- Water and nicotine

Solution Formation by Hydrogen Bonding:

There are some compounds which are not ionic still they are soluble in water, for example ethyl alcohol and sugar. These compounds are soluble due to hydrogen bonding be-



Hydrogen bonding between ethyl alcohol and water molecules

tween the polar molecules and those of water molecules. It is shown below:

Q7: Compare/differentiate solution, suspension and colloids. (Malakand 2018, Abbottabad 2019)

Ans. **Solution:**

1. A homogeneous mixture of two or more than two substances is called a solution.
2. A solution has a uniform composition throughout its mass.
3. Solute particles in solution cannot be seen with naked eye.
4. During filtration, solute particles can pass through the pores of filter paper.
5. If solution is allowed to stand, the solute particles do not settle solution.

Example: Sodium chloride solution

Suspension:

1. A heterogeneous mixture of two or more substances is called suspension.
2. Suspension do not have a uniform composition.
3. In suspension the solute particles can be seen with naked eye.
4. Particles of the solute cannot pass through the pores of filter paper.
5. If suspension is allowed to stand, solute particles settle down.

Example: A mixture of chalk in water, medicines

such as anti-acid, antibiotics and paracetamol.

Colloids:

1. Colloidal are heterogeneous in which solute particles are larger than those present in the true solution, but not too large to be seen with naked eye.
2. In colloids the particles are intermediate in size between those in solutions and suspensions.
3. Solute particles are not homogenized with solvent.
4. The solute particles are small enough, so cannot be seen with naked eye.
5. The solute particles can pass through the pores of filter paper slowly.
6. If the colloidal solution is allowed to stand, the solute particles do not settles down at the bottom.

SCIENTIFIC INFORMATION [Tyndall Effect]

Many colloids appear homogeneous because the individual particles cannot be seen. The particles are however, large enough to scatter light. This effect is known as Tyndall effect. Tyndall effect occurs when light is scattered by colloidal particles dispersed in a transparent medium. The Tyndall effect is a property that can be used to distinguish between a solution and a colloid. The term colloid was introduced by Graham. Greek; Kolla means glue, Eidos means like.

EXAMPLE 6·6: Which solvent-liquid ammonia [NH_3] or benzene [C_6H_6] is more likely to dissolve each of the following solutesA: (a) H_2O (b) C_6H_{12} (c) AgCl

Solution:

(a) H_2O is more likely to dissolve in NH_3 because both substances are polar and capable of hydrogen bonding formation.

(b) C_6H_{12} [hexene] is more likely to dissolve in non-polar solvent like benzene [C_6H_6].

(c) AgCl is more likely to dissolve in the polar solvent ammonia [NH_3].

PRACTICE PROBLEM 6·2:

Which type of solvent, polar or non-polar is most likely to dissolve methyl alcohol [CH_3OH].

Solution: As methyl alcohol is a polar in nature so a polar solvent like water is most likely to dissolve it.

Q8: Write down the distinctive properties of solutions, colloids and suspensions.

Solutions	Colloids	Suspensions
1. Homogeneous	Heterogeneous	Heterogeneous
2. Particle size 0·01 - 1nm; can be atom, ions or molecules	Particles size 1-1000 nm, dispersed, can be aggregates or large molecules	Particle size, over 1000nm, suspended, can be large particles or aggregates

3. Do not separate on standing/resting	Do not separate on standing.	Particles settle down
4. Cannot be separated by filtration	Cannot be separated by filtration	Can be separated by filtration
5. Do not scatter light	Scatter light [Tyndall effect]	May scatter light but are not transparent
6. Particles are so small that they can't be seen with naked eye	Particles are big but can't be seen with naked eye and can be seen with powerful microscope.	Particles are big enough to be seen with naked eye

Exercise

Choose the correct option:

1. Which of the following solution is more dilute?
   (a) 1·0M (b) 0·5M
   (c) 0·05M **(d) 0·005M✓**
2. Milk is an example of:
   (a) Solution
   (b) Saturated solution
   (c) Colloids solution✓
   (d) Suspension
3. Water drop in air is an example of solution:
   (a) Gas in gas (b) Gas in liquid
   (c) Liquid in gas✓ (d) Liquid in liquid
4. When there is a low concentration of solute in solution, it is known as:
   (a) Dilute solution✓
   (b) Saturated solution
   (c) Concentrated solution
   (d) Super saturated solution
5. What is the molarity of $NaNO_3$ solution made by diluting $250cm^3$ of a 1·60M solution to a final volume of $400cm^3$?
   (a) 1·20M **(b) 1M✓**
   (c) 0·200M (d) 0·160M

Solution:

$V_1 = 250cm^3 : V_2 = 400cm^3$:

$M_1 = 1·60$, $M_2 = ?$

$$M_1V_1 = M_2V_2 \text{ (OR) } M_2 = \frac{M_1V_1}{V_2} = \frac{1{\cdot}60 \times 250}{400}$$

$= \boxed{1M}$

6. What is the concentration in % mass by volume (m/v) of a solution, containing 15 gram KCl in $600cm^3$ solution?

(a) 5% (b) 2%

(c) 0·200% **(d) 2·50%✓**

Solution:

$$\%\frac{m}{v} = \frac{\text{mass of solute}}{\text{volume of solution}} \times 100 :$$

$\frac{15}{600} \times 100 : (2{\cdot}5)$

7. When KCl dissolves in water, the following will be produced:

(a) K and Cl **(b) K^+ and $\bar{C}l$ ✓**

(c) K and Cl_2 (d) K^+ and Cl_2

8. 2 moles of Na_2SO_4 are dissolved in 1dm3 of solution. Molarity solution is:

(a) 1M **(b) 2M✓**

(c) 3M (d) 0·5M

Solution:

$$\text{Molarity} = \frac{\text{number of moles}}{\text{volume of solution in } dm^3}$$

$$M = \frac{2 \text{ moles}}{1dm^3} = (2mol{\cdot}dm^{-3}) \text{ or } 2M$$

9. Molarity is the number of moles of solute dissolved in:

(a) 1Kg of solvent (b) 1Kg of solution

(c) $1dm^3$ of solvent **(d) $1dm^3$ of solution✓**

10. The molarity of NaOH solution by dissolving 4-grams of it in 250mL water is:

(a) 0·4M✓ (b) 0·8M

(c) 0·2M (d) 0·1M

Solution:

$$M = \frac{\text{mass of solute}}{\text{molar mass of solute} \times \text{volume of solution}\,(dm^3)}$$

$$M = \frac{4}{40 \times 0{\cdot}25} = \frac{4}{10} = [0{\cdot}4M]$$

As $\frac{250mL}{1000} = (0{\cdot}25 \text{ litre})$

﴿اقوال النبی ﷺ﴾

- درختوں کے پھل مت بیچا کرو جب تک کہ ان میں صلاحیت ظاہر نہ ہو جائے۔
- دو خصلتیں کسی ایماندار آدمی میں جمع نہیں ہو سکتیں، ایک بخل اور دوسری بد خلقی۔
- غیر کے لیے کوئی صدقہ نہیں جب قریبی رشتہ دار محتاج ہیں۔
- بہتر صدقہ وہ ہے جو صاحب توفیق دے اور اپنے عیال سے شروع کریں۔
- نیکی کا بتانا نظامثل اس کے کرنے کے ہے۔

Numerical Questions

Solve the following numerical questions:

Q1: What is the molarity of a solution composed of 5·85 grams of potassium iodide [KI] dissolved in enough water to make 0·125dm^3 of solution.

Solution:

Mass of potassium iodide [KI] = 5·85g

Molar mass of KI: 39 + 127 = 166 g/mol

Volume of solution= 0·125dm^3

By using the molarity formula

$$\text{Molarity} = \frac{\text{mass of solute}}{\text{molar mass of solute} \times \text{volume of solution in } dm^3}$$

$$M = \frac{5·85}{166 \times 0·125} = \frac{5·85}{2075} = (0·281M)$$

Q2: How many moles of H_2SO_4 are present in 0·500dm^3 of 0·150M H_2SO_4 solution?

Solution:

Number of moles of H_2SO_4 = n = ?

Volume of solution = v = 0·500dm^3

Molarity = M = 0·150$mol \cdot dm^{-3}$

Formula used

$$\text{Molarity} = \frac{\text{number of moles}}{\text{volume in } dm^3}$$

Number of moles = (n) = M x volume in dm^3

$$n = 0·150 mol \cdot dm^{-3} \times 0·500 dm^3$$

$$[n = 0·075 \text{ moles}]$$

Q3: Suppose you want to dissolve 40 grams NaOH in enough H_2O to make 6dm^3 of solution.

(a) What is the molar mass of NaOH?
(b) What is the molarity of this solution?

Solution:

Mass of NaOH = 40 grams

Volume of solution = $6dm^3$

Molar mass of NaOH = $23 + 1 + 16 = 40\ g \cdot mol^{-1}$

(a) Molar mass of NaOH = the summation of the atomic masses of all atoms present in a molecule is called molecular mass. When molecular mass is taken in grams, then it is called molar mass. Molar mass of NaOH = $40g \cdot mol^{-1}$.

(b) Molarity of the solution

$$M = \frac{\text{mass of solute}}{\text{molar mass of solute} \times \text{volume of solution in } dm^3}$$

$$M = \frac{40\ grams}{40\ g \cdot mol^{-1} \times 6dm^3} = \frac{1}{6} = \left[0{\cdot}166\ mol \cdot dm^{-3}\right]$$

Q4: What is the molarity of a solution of 14 grams NH_4Br in enough water to make $150cm^3$ of solution?

Solution:

Molarity of solution = M = ?

Mass of solute (NH_4Br) = 14 grams

Molar mass of $NH_4Br = 14 + 4 + 80 = 98\ g \cdot mol^{-1}$

$$\text{Volume of solution} = \frac{150cm^3}{1000} = 0{\cdot}150dm^3$$

$$\text{Molarity} = \frac{\text{mass of solute}}{\text{molar mass of solute} \times \text{volume of solution } (dm^3)}$$

$$M = \frac{14 grams}{98 g \cdot mol^{-1} \times 0{\cdot}150dm^3} = \frac{14}{14{\cdot}7} = \left[0{\cdot}953\ mol \cdot dm^{-3}\right]$$

Q5: Suppose you want to produce $1dm^3$ of 350M solution of H_2SO_4:
(a) What is the solute?
(b) What is the solvent?
(c) How many grams of solute is needed to make this solution?

Solution:

(a) H_2SO_4 will be the solute.

(b) H_2O will be the solvent.

(c) Volume of solution = $1dm^3$

Molarity = $M = 3.50\ mol \cdot dm^{-3}$

Molar mass of $H_2SO_4 = 2 + 32 + 64 = 98\ g \cdot mol^{-1}$

$$\text{Molarity (M)} = \frac{\text{mass of solute}}{\text{molar mass of solute x volume of solution}}$$

Mass = M x molar mass x volume of solution

Mass = $3.50 mol \cdot dm^{-3} \times 98 g \cdot mol^{-1} \times 1dm^3$

= [343 grams]

Short Questions

Q1: Is sea water a solution? How would you prove with a simple experiment whether it is pure water or a solution?

Reasons: Sea water is a solution. It contains dissolved minerals and salts. It also contains dissolved gases like oxygen.

1. We can differentiate between pure water and sea water [solution] by passing electric current from both. As pure water has no free ions or electrons to move so current

will not pass through it. On the other hand, sea water contains anions and cations [Na^{+}, Ca^{+2}, Mg^{+2}, $\bar{C}l$, SO_4^{-2}, NO_3^{-1}] due to dissolved mineral salts. As there is a free moment of ions in sea water, so electric current will pass through it.

2. Sea water will have different taste, pH, melting point, boiling point than pure water.

OR we can also made a difference between pure water and sea water, that sea water contains suspended and un-dissolved particles which can be clearly seen with the help of a microscope.

Q2: A bottle in a drug store contains a label "3 percent hydrogen peroxide" what does it mean?

Ans. It means that 3ml [cm^3] of hydrogen peroxide [H_2O_2] have been dissolvent in enough water [solvent] to make the total solution 100mL. It also means that each 100mL solution contains 3mL of hydrogen peroxide.

Q3: Classify the following as solution, colloid or suspension and explain why? (1) Milk (2) Hot cup of tea (3) Orange juice with pulp (4) Mayonnaise (5) Listerine mouth wash (6) Milk of magnesia (7) Cheese (8) Mist (9) Bottled water

Ans.

1. Milk is the example of colloids.
2. Hot cup of tea, most likely to be a solution but is a suspension in other regard, so its both caffeine and other water soluble sub-

stances are present in it.

3. Orange juice with pulp → suspension
4. Mayonnaise [colloid] → a thick creamy cold sauce, made from oil, vinegar and yellow part of egg.
5. Listerine mouth wash [solution]
6. Milk of magnesia, a white suspension of hydrated magnesium carbonate in water, used as an antacid or laxative (قبض کشا).
7. Cheese [colloid]
8. Mist [suspension]
9. Bottled water [solution]

Q4: Why we stir paints thoroughly before using it?

Ans. Paint is a suspension of chemicals, colours and water. The solute particles settle down when left undisturbed for a long time and hence the paint needs to be stirred before using, so that the components must distribute uniformly.

Q5: Why suspensions and solutions do not show Tyndall effect, while colloids do?

Ans. Suspensions and solutions do not show Tyndall effect because in suspensions particles are so big that light is blocked and difficult to scatter but colloids can show Tyndall effect because particles scatter (بکھیرنا) or disperse light rays thus illuminate the path of light i.e. exhibit the Tyndall effect. Similarly in solutions particles sizes are too much small so can't scatter the light rays and hence do not exhibit Tyndall effect.

Long Questions

Q1: Define solution. Explain types of solution on the basis of states of matter.

Ans. "A homogeneous mixture of two or more substances is called a solution." Based on the physical states of matter/solute and solvent there are nine different types of solutions.

Physical State	Solute in Solvent	Example
Solution of gases	Gas in gas Gas in liquid Gas in solid	Air [oxygen in nitrogen] CO_2 in cold drinks H_2 gas adsorbed at platinum metal surface
Solutions of liquids	Liquid in gas Liquid in liquid Liquid in solid	Fog [water vapours in air] Alcohol in water Dental amalgam [Hg in Ag]
Solutions of solids	Solid in gas Solid in liquid Solid in solid	Smoke [carbon particles in air] Sodium chloride in water Bronze alloy [copper and zinc]

Q2: (a) Discuss the solubility of a substance.
(b) Explain the factors that are responsible for the solubility of a substance.

Ans. Please see question # 4.

Q3: (a) What is the differences between a concentrated and a dilute solution?
(b) Differentiate between unsaturated, saturated and super saturated solutions.

Ans. (a) Please see question # 1.
(b) Please see question # 1.

Q4: Describe one way to prove that a mixture of sugar and water is a solution and that a mixture of sand and water is not a solution.

Ans.

1. As sugar form a homogenous mixture with water so a mixture of sugar and water is a solution. On the other hand, sand do not form a homogenous mixture with water so a mixture of sand and water is not a solution..
2. Sand can be separated from water by filtration but sugar cannot be separated from water by filtration.
3. Sand is visible in water, while sugar is invisible.

Q5: Explain the following concentration units.
(a) Percentage composition
(b) Molarity

Ans. Please see question # 2.

❐❐❐

CHAPTER

7 ELECTROCHEMISTRY

Electrochemistry:

"The branch of chemistry which deals with the study of inter-conversion of chemical energy and electrical energy is called electrochemistry."

Electrical energy $\rightleftharpoons$ Chemical energy

Q2: Explain oxidation-reduction in detail. (Bannu 2019)

Ans. Oxidation - reduction or redox reactions are those reactions during which loss and gain of electrons takes place. Whenever there is oxidation there must be reduction. The number of electrons lost in a chemical reaction must be equal to the total number of electrons gained:

Oxidation:

Oxidation can be defined by a number of ways.

a) Addition of oxygen to a substance is called oxidation. For example,

$C + O_2 \longrightarrow CO_2$

$2Cu + O_2 \longrightarrow 2CuO$

b) Removal of hydrogen is called oxidation

$2NH_3 + 3Cl_2 \longrightarrow N_2 + 6HCl$

$Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2$

c) Loss of electrons is called oxidation

$Fe \longrightarrow Fe^{+2} + 2\bar{e}s$

$Fe^{+2} \longrightarrow Fe^{+3} + 1\bar{e}$

$Na \longrightarrow Na^{+1} + 1\bar{e}$

d) Addition of electronegative element to an element or compound is called oxidation.

$S + Cl_2 \longrightarrow SCl_2$

(or) $2S + Cl_2 \longrightarrow S_2Cl_2$

$SnCl_2 + Cl_2 \longrightarrow SnCl_4$

Reduction:

a) Removal of oxygen from a substance is called reduction.

$2HgO \xrightarrow{Heat} 2Hg + O_2$

$PbO + H_2 \longrightarrow Pb + H_2O$

b) Addition of hydrogen is called reduction.

$N_2 + 3H_2 \longrightarrow 2NH_3$

$Cl_2 + H_2 \longrightarrow 2HCl$

$C + 2H_2 \longrightarrow CH_4$

c) Gain of electrons is called reduction.

$Sn^{+4} + 2\bar{e} \longrightarrow Sn^{+2}$

$Fe^{+2} + 2\bar{e} \longrightarrow Fe^{\circ}$

d) Removal of electronegative element from a compound is called reduction.

$2FeCl_3 + H_2 \longrightarrow 2FeCl_2 + 2HCl$

R e d — Reduction

O x — Oxidation

Lets take an example of a redox reaction.

Consider the reaction between sodium [Na] and chlorine [Cl_2]. This reaction involves the transfer of electrons from sodium atom to chlorine atom. Sodium loses an electron and is said to be oxidized to sodium ion, while chlorine atom gains an electron and is reduced to chloride ion ($\bar{C}l$). Those reactions in which loss and gain of electrons takes place simultaneously are called redox / oxidation - reduction reactions.

$$2Na + Cl_2 \longrightarrow 2NaCl$$

$$Na \rightarrow Na^+ + 1\bar{e} \qquad Cl + 1\bar{e} \rightarrow \bar{C}l$$

Q2: Define oxidation state. Write down rules for assigning oxidation states.

Ans. **Oxidation State:**

"The apparent charge on an atom in a molecule or compound is called oxidation state." It is also called oxidation number. It may be positive, negative or even zero. Unlike ionic charges, oxidation numbers do not have an exact meaning. Oxidation numbers are useful in naming compounds, in writing formulae and in balancing chemical equations. The colours of solutions changes with the change of oxidation state. i.e.

Cr^{+2} = Blue, Cr^{+3} = Green, Cr^{+6} = Orange

Rules for Assigning Oxidation Number:

1. The oxidation number of all elements in the free state is zero. For example, the oxidation number of H_2, Cl_2, Na etc is zero.

2. The oxidation number of a simple ion is the same as the charge on it, for example, oxidation numbers of Na^{+1}, Ca^{+2}, Al^{+3} and Br^{-1} are +1, +2, +3 and -1 respectively.

3. The oxidation number of hydrogen in its compounds is +1, while in case of metal hydrides, it has -1 oxidation state. e.g. NaH: Na = +1 and H = -1.

4. The oxidation number of oxygen in its compounds is -2, while in case of peroxides, its oxidation state is -1. In case of OF_2 it is +2, in case of superoxides, it is -1/2.

5. The oxidation number of each element of group IA, IIA and IIIA is +1, +2 and +3 respectively.

6. The oxidation number of each element of group VIIA [halogens] in their binary compounds is -1.

7. In neutral molecules, the algebraic sum of the oxidation numbers of all the elements is zero. For example H_2SO_4

$2H = +2$

$S = +6$

$4(O) = -8$

0

8. In ions, the algebraic sum of oxidation numbers is equal to the charge on the ion. For example, MnO_4^{-1}

$4(O) = -8$

$\underline{Mn = +7}$

-1

9. In any substance the more electronegative atom has the negative oxidation number.

10. The same element may show different oxidation number in different compounds, e.g. CO [C=+2, O=-2] CO_2=C=+4, O_2^{-4}

EXAMPLE 7.1: Determine the oxidation number of phosphorus in phosphorus pentachloride.

Solution: We know that the oxidation number of chlorine atom is -1. To make the total of all the oxidation numbers for PCl_5 equal to zero. The phosphorus must have an oxidation number of +5. Let X, equal to oxidation number of phosphorus in PCl_5 then:

X	+	5	(-1)	=	0
Oxidation number of phosphorus		Number of chlorine atoms	Oxidation number of each chlorine atom		Charge on molecule

(or) $PCl_5 = 0$

$P + 5(Cl) = 0$

$P + 5(-1) = 0$

$P - 5 = 0$

$\boxed{P = +5}$

EXAMPLE 7.2: What is the oxidation number of nitrogen in the nitrite ion NO^{-1}_2?

Solution:

X	+ 2	(-2)	= -1
Oxidation number of nitrogen	Number of oxygen atoms	Oxidation number of each oxygen atom	Charge on nitrite molecule

$NO_2 = -1$

$N + 2(O) = -1$

$N + 2(-2) = -1$

$N - 4 = -1$

$N = -1 + 4 \Rightarrow [N = +3]$

PRACTICE PROBLEM 7·1:

Determine the oxidation number of carbon in CO· What is the oxidation number of sulphur in sulphite (SO^{-2}_3) ion?

Solution:

$CO = 0$	SO_3^{-2}
$C + (O) = 0$	$S + 3(O) = -2$
$C + (-2) = 0$	$S + 3(-2) = -2$
$C - 2 = 0$	$S - 6 = -2$
$\boxed{C = +2}$	$S = -2 + 6$
	$\boxed{S = +4}$

EXAMPLE 7·3: What are the three possible oxidation states of sulphur?

Solution: *We know that sulphur is an element of group VIA of the periodic table· According to group number, it has 6 outermost electrons so its maximum oxidation state can be +6· In elemental state [free state], its oxidation state = zero [0]· Its other oxidation states are +4, +2*

and the minimum is -2, which are not explained [covered by the rules given so far].

PRACTICE PROBLEM 7.2:
What are the three possible oxidation states of copper [Cu]? What is the minimum oxidation number of silver?

Solution: The three possible oxidation sates of copper are:

Cu^{+1}, Cu^{+2}, Cu^{+3}

$\overset{+1}{Cu_2}\overset{-2}{O}$: $\overset{+2}{Cu}\overset{-2}{O}$: $\overset{+1}{K}\overset{+3}{Cu}\overset{-4}{O_2}$

The minimum oxidation number of Ag is zero when it is in element [free] state.

Q3: Explain oxidizing and reducing agents in detail by giving examples.

Ans. **Oxidizing Agents:**

Definition: "The species which oxidizes other substances and themselves being reduced are called oxidizing agents." According to the classical concept an oxidizing agent is a substance which:

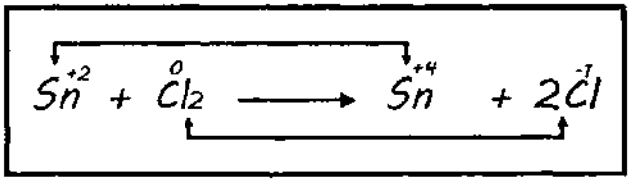
a) Provide oxygen to other substances
b) Remove hydrogen from other substances
c) Remove electrons from other substances
d) The oxidation state of oxidizing agent decreases

EXAMPLE 7.4: Consider the reaction below:

$$\overset{0}{Zn} + \overset{+2\ -2}{CuO} \longrightarrow \overset{+2\ -2}{ZnO} + \overset{0}{Cu}$$

Solution: Oxidation number of Cu in CuO = +2
Oxidation number of Cu = 0 in the right side = 0
It means that the oxidation state of Cu has decreased from $+2 \rightarrow 0$, so CuO act as an oxidizing agent in the above reaction. Similarly Cu of CuO has removed electrons from zinc Zn [$Zn^{0} \rightarrow Zn^{+2} + 2\bar{e}$], so it is an oxidizing agent.

EXAMPLE 7.5: Consider the reaction:



Solution: Oxidation number of Cl_2 is zero.
Oxidation number of chloride ion [Cl^{-1}] = -1
The oxidation state of Cl_2 is decreased from zero to -1 so chlorine is an oxidizing agent in the above reaction. Beside this chlorine has removed electrons from Sn^{+2} [stannous ion], so electrons remover specie is also called an oxidizing agent.

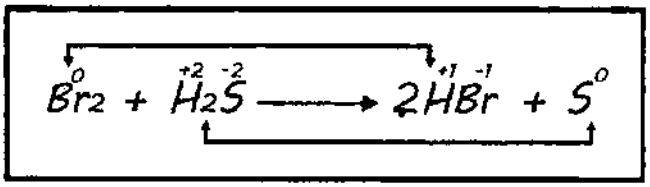
REDUCING AGENTS:

Definition: "Substances which reduce other and themselves get oxidized are called reducing agents." Examples are; hydrogen sulphide [H_2S], sulphur dioxide [SO_2], Na, Al, Mg. According to classical concept, a reducing agent:

a) Remove oxygen from other substances
b) Provide hydrogen to other substances
c) Provide electron to other substances
d) The oxidation number of reducing agent in-

creases during a redox reaction.

Consider the following reaction:



Oxidation number of sulphur in H_2S = -2

Oxidation number of free sulphur = 0

There is an increase in oxidation number of "S" from -2 to 0, so H_2S is a reducing agent. Similarly sulphur has donated electrons to bromine, so electrons provider is also called reducing agent.

Examples of Oxidizing and Reducing Agents:

Oxidizing Agents	Reducing Agents
Bromine [Br_2]	Carbon (C)
Chlorine [Cl_2]	Carbon monoxide (CO)
Concentrated sulphuric acid	Hydrogen [H_2]
Nitric acid [HNO_3]	Hydrogen sulphide [H_2S]
Oxygen [O_2]	Metals
Potassium permanganate (VII) [$KMnO_4$]	Potassium iodide [KI]
Potassium dichromate (VI) [$K_2Cr_2O_7$]	Sulphur dioxide [SO_2]

SCIENTIFIC INFORMATIONS

Fireflies contain special cells in their abdomens that produce light. These cells contain a chemical

called luciferin, which undergoes oxidation and produces light when the firefly takes in oxygen. Ozone is a very strong oxidizing agent and used in manufacturing of decoulorizing agents or as oxidants of organic materials. When oxygen is used as an oxidizing agent, at high temperature and pressure by dissolving it in waste water. The process is known as wet oxidation. It is considered as an effective method of oxidizing organic materials and removal of toxic compounds.

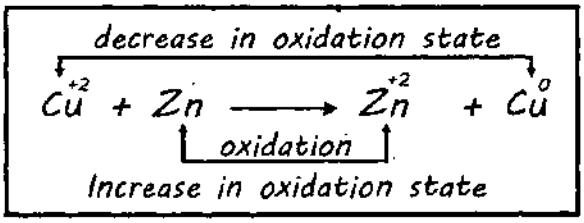
Q9: What are oxidation-reduction reactions? Give suitable examples.

Ans. **Oxidation-Reduction Reactions:**
(BISE Malakand 2018, Mardan 2019)
"Chemical reactions in which oxidation and reduction take place simultaneously are called oxidation-reduction reactions." These are also called redox reactions.

Example:

$$CuSO_4 + Zn \longrightarrow ZnSO_4 + Cu$$

The overall ionic equation is:



Actually the redox reactions consist of two half reactions, oxidation half reaction and reduction half reaction. Let consider the following redox

reaction:

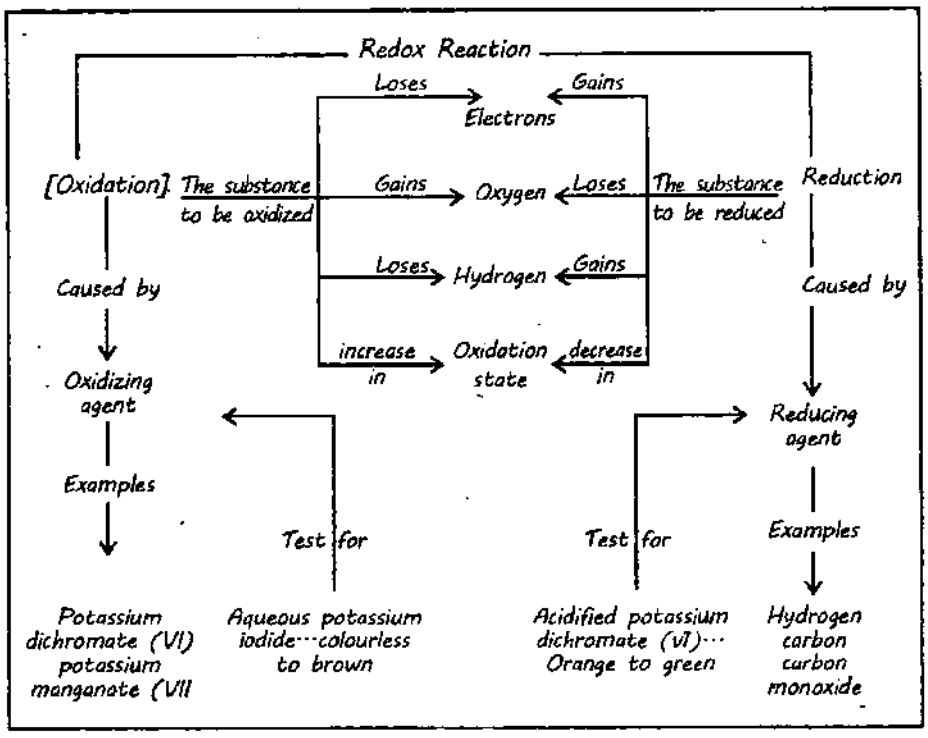
$$2Na^{\circ} + I_2^{\circ} \longrightarrow 2Na^{+} + 2I^{-}$$

This reaction can be written in the form of two half reactions as;

$$2Na \longrightarrow 2Na^{+} + 2\bar{e}s \quad [oxidation]$$

$$I_2 + 2\bar{e} \longrightarrow 2I^{-} \quad [reduction]$$

In the 1st half reaction, loss of electrons takes place. This reaction is called an oxidation half reaction. In the 2nd half reaction, gain of electrons takes place. This reaction is called reduction half reaction.



Q5: Explain the basic concepts of electrolytes.

Ans. Some of the basic concepts of electrolytes are given below:

Electrolytes:

(Malakand 2018, Kohat, Abbottabad 2019)

Definition: *"Substances which ionize into positive and negative ions in their aqueous solutions are called electrolytes." The aqueous solutions of electrolytes conduct electricity. e.g.*

Salt: $NaCl \xrightarrow{H_2O} Na^+_{(aq)} + \bar{C}l_{(aq)}$

Acid: $HCl \xrightarrow{H_2O} H^+ + \bar{C}l$

Salt: $KCl \xrightarrow{//} K^+ + \bar{C}l$

Base: $NaOH \xrightarrow{//} Na^+ + \bar{O}H$

It is clear from the above examples that an electrolyte may be acid, base and salt.

Strong Electrolytes:

Definition: *"Substances which ionize upto large extent and conduct electricity upto maximum extent are called strong electrolytes." For example;*

$HCl \xrightarrow{H_2O} H^+_{(aq)} + \bar{C}l_{(aq)}$ *[92%]*

$NaOH \xrightarrow{H_2O} Na^+_{(aq)} + \bar{O}H_{(aq)}$ *[84%]*

Weak Electrolytes:

Definition: *"Substances which ionize upto limited extent are called weak electrolytes."*

Example: $CH_3COOH \rightleftharpoons[H_2O] CH_3C\bar{O}O_{(aq)} + H^+_{(aq)}$

[1.3%]

$NH_4OH \rightleftharpoons[H_2O] \overset{+}{N}H_4 + \bar{O}H$

[1.3%]

Non-Electrolytes:

Definition: *"Substances which do not ionize in aqueous solutions and thus their aqueous solu-*

tions do not conduct electricity are called non-electrolytes." Examples are: glucose, urea and sugar.

Electrodes:

"The metallic plates, rods or wires through which electrons enter or leave the electrolyte in a cell are called electrodes." Charged metallic plates are called electrodes.

Anode:

"The electrode which is connected to the positive terminal of the battery is called anode." (OR)
"The positive electrode is called anode." Anions move towards anode and leave the electron in electrolytic cell. Oxidation occurs at anode.

Cathode:

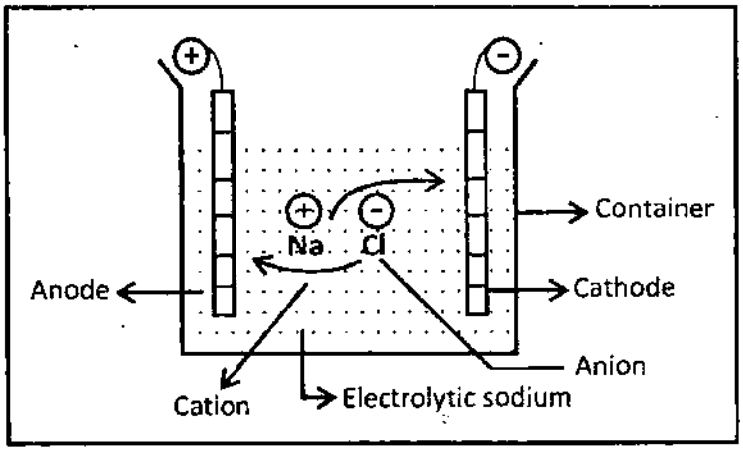
"The electrode which is connected to the negative terminal of the battery is called cathode." (OR)
"The negative electrode is called cathode." Cations move towards cathode and gain the electrons in electrolytic cell.

Anions:

Negatively charged ions are called anions. For example, $\bar{C}l, \bar{O}H$ etc.

Cations:

Positively charged ions are called cations. For example, $Na^{+}, Ca^{+2}, \overset{+}{N}H_4, Al^{+3}$



SCIENTIFIC INFORMATIONS

Passing an electric current through a substance may produce a temporary change such as lighting up of an electrical bulb or a permanent change like electroplating. Metals are good conductors of electricity. gold and silver are the best electrical conductors but due to their high cost value most of the electrical wires are made of copper and aluminum.

Q6: What are electrochemical cells? Explain various types of electrochemical cells in detail.

Ans. Electrochemical Cells: (Peshawar 2019)

Definition: "Electrochemical cells are devices in which interconversion of electrical and chemical energies takes place." There are two types of electrochemical cells.

1. *Electrolytic cell*
2. *Galvanic or voltaic cell*

1. Electrolytic Cell:

Definition: "A cell in which electric current is used to produce a redox reaction is called an electrolytic cell." In electrolytic cell electrical energy is converted into chemical energy. Examples are; Down and Nelson's cell.

Electrolysis:

"Electro" means electrolyte and "lysis" means breaking/splitting. "The process of dissociation or decomposition of an electrolyte by passing electric current through its solution or fused state is called electrolysis."

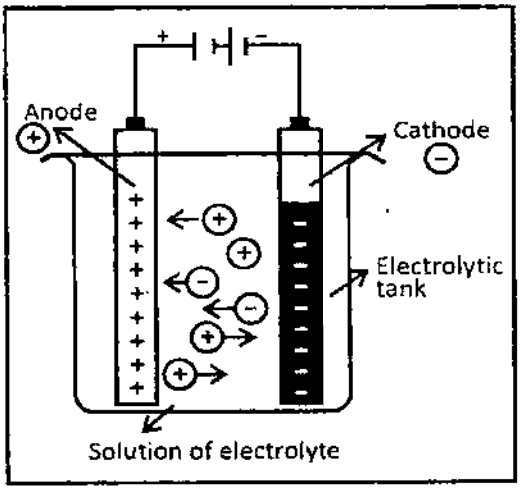
Construction:

Electrolytic cell consists of a vessel which contain electrolyte . solution. It has two metallic plates. These plates are called electrodes. Through these plates, electrons enter and leave the cell. The electrodes are connected to direct current source. The electrode which is connected to the positive terminal [end] of the battery is called anode, while the electrode which is connected to the negative terminal of the battery is known as cathode. Electrolyte decomposes into positive ions [cations] and negative ions [anions].

Working:

When the electrodes are connected to the battery and electric current is passed through the electrolytic cell, the ions in the electrolyte solu-

tion moves towards their respective electrodes. The anions liberate electrons at anode. These electrons pass through outer circuit to the cathode. The cations which surround the cathode, consume these electrons. Hence, the number of electrons lost is always equal to the number of electrons gained.



The battery continuously supplying electrons to the cathode and receiving electrons from the anode. The anion moves towards anode and discharge their electron(s) there and thus oxidation takes place at anode. The cations move towards cathode and gain the electron(s) there and thus reduction takes place at cathode.

Example:

When electric current is passed from the fused sodium chloride [NaCl], the following reactions take place during the process.

$$2NaCl_{(s)} \longrightarrow 2Na^{+}_{(aq)} + 2\bar{C}l_{(aq)}$$

(cations) (anions)

At anode: $2Cl^{-1}_{(aq)} \longrightarrow Cl_2 + 2\bar{e}s$ [oxidation]

At cathode: $2Na^{+1}_{(aq)} + 2\cancel{e} \longrightarrow 2Na$ [reduction]

Overall reaction: $2Na^{+} + 2\bar{C}l \longrightarrow 2Na + Cl_2$

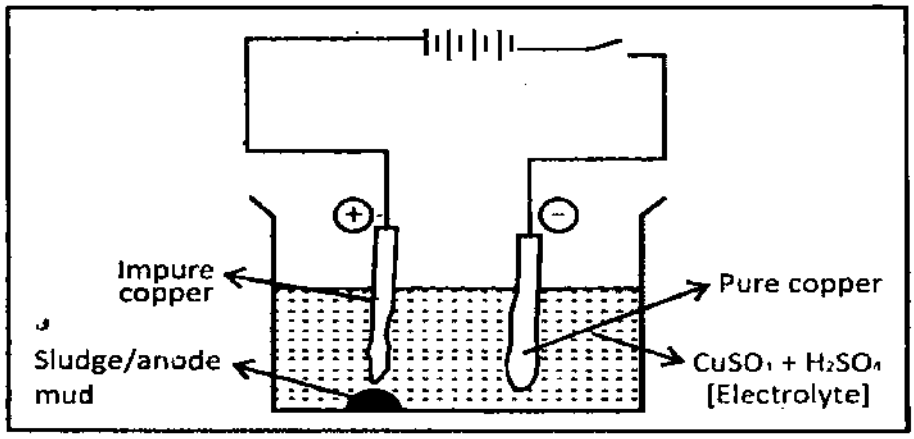
Ano ↓ Anode	The ox ↙ Oxidation	red ↓ Reduciton	the	Cat ↓ Cathode

Q7: Write a note on electrolytic refining of copper.

Ans. When copper is extracted from its sulphide ore, it is called blistered copper. Because blisters (⊥T) are present on its surface, so it is called blistered copper. Blistered copper is 99% pure. The impurities present are Aurium [Au], Argentums [Ag] and Platinum [Pt].

Process:

Large slabs of impure copper are made the anode and a thin piece of pure copper is made the cathode. A mixture or acidified solution of $CuSO_4$ is used as an electrolyte. The operation is performed at 50C° and 0·3V voltage is supplied. The optimum current density used is 160 - 400A/m^2.



When the electric current is passed, the impure copper dissolves at the anode to form Cu^{+2} ions. The Cu^{+2} ions are reduced at cathode to copper atoms. The pure copper deposits at cathode.

At anode: $Cu \longrightarrow Cu^{+2} + 2\bar{e}s$ [oxidation]

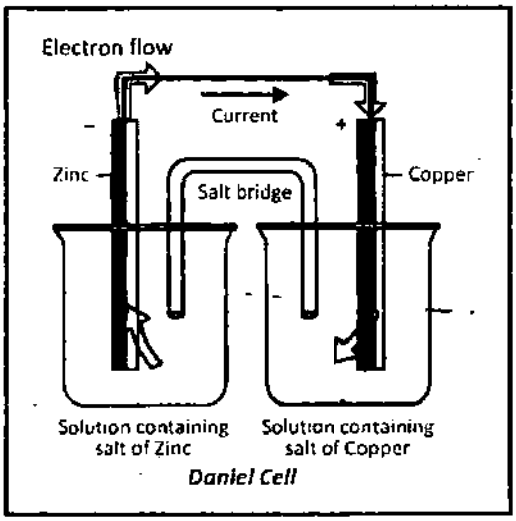
At cathode: $Cu^{+2} + 2\bar{e} \longrightarrow Cu$ [reduction]

During this process the less active metals, for example Au, Ag remain undissolved and settle at the bottom of the cell as anode sludge (گنہ) which is processed to recover these precious (قیمتی) metals. The temperature and voltage conditions are such that only copper is deposited at the cathode. By electrolytic refining process upto 99.99% pure copper is obtained.

Q8: Write a detailed note on galvanic or voltaic cell.

Ans. Galvanic Cell/Voltaic Cell: (Bannu 2019)

Definition: "The type of electrochemical cell which produces electric current as a result of redox reaction is known as galvanic cell." Galvanic cell converts chemical energy into electrical energy. Its common



Daniel Cell

example is Daniel cell.

Construction of Daniel Cell:

"A galvanic cell consists of two separate containers each container is called a half cell. One half cell consists of zinc - rod dipped in 1 molar $ZnSO_4$ solution and the other half cell consists of copper rod, placed in 1 molar copper sulphate solution. Internally the two solutions are connected by a salt bridge. A salt bridge is U-shaped tube. This tube is filled with electrolyte gel, such as KCl, K_2SO_4 or Na_2SO_4 solution called as the agar. The salt bridge interconnects the two solutions in the anode container and the cathode container. A salt bridge performs three basic functions:

1. It allows electrical contact between the two solutions.
2. It prevents the mixing of the two solutions.
3. It keeps electrical neutrality in each half cell.

The electrodes are connected by a wire and a voltmeter is inserted (V) in the circuit to measure the current.

Working of the Cell:

The zinc metal has tendency to lose electrons more readily than copper when the circuit is completed. As a result oxidation takes place at zinc electrode, the electrons flow from zinc electrode through the external circuit to copper electrode. These electrons are gained by copper ions of the cathodic solution and deposited as

copper atoms at the cathode.

Electrons travel in external circuit, while ions move through the salt bridge and in this way electric current is produced. The two half reactions are as follow:

Anode Half Reaction:

$$Zn_{(s)} \longrightarrow Zn^{+2}_{(aq)} + 2e$$

Cathode Half Reaction:

$$Cu^{+2}_{(aq)} + 2e \longrightarrow Cu_{(s)}$$

Overall Reaction:

$$Zn + Cu^{+2}_{(aq)} \longrightarrow Zn^{+2}_{(aq)} + Cu$$

The batteries which are used in automobiles, calculators, toys etc and to light the bulbs work on the same principle.

Q9: Differentiate between electrolytic cell and galvanic cell.
(Mardan 2018)

Ans. Differences between Galvanic Cell and Electrolytic Cell are as follow:

1. A galvanic cell converts chemical energy into electrical energy while an electrolytic cell converts electrical energy into chemical energy.
2. In galvanic cell the redox reaction is spontaneous and is responsible for the production of electrical energy while in electrolytic cell the redox reaction is non-spontaneous and electrical energy must be supplied to start the reaction.

3. In galvanic cell, the two half cells are set up in different containers and for connection a salt bridge is required while in electrolytic cells, both the electrodes are placed in the same container, in the solution of molten electrolyte, no need of salt bridge.
4. The anode is negative and cathode is the positive electrode in galvanic cell while in electrolytic cell, the anode is positive and cathode is the negative electrode.
5. In galvanic cell, oxidation occurs at anode and reduction occurs at cathode, similar is the case of an electrolytic cell.
6. In galvanic cell, the electrons are supplied by the species getting oxidized. They move from anode to cathode in external circuit while in electrolytic cell, the external battery supplies the electrons. They enter through the cathode and come out through the anode.

Q10: Define battery. What are the various types of batteries? Explain dry cell in detail.

Ans. **Battery:** (Swat 2019)

Definition: A cell in which chemical energy is converted into electrical energy is called battery."

(OR)

"A group or combination of galvanic cells joined in series is called battery." For example, car batteries consist of six or more identical / similar gal-

vanic cells connected in series. A battery is a self contained, chemical power pack that can produce a limited amount of electrical energy. Various types of batteries are:

1. **Primary Batteries:** These batteries are not reversible and once discharged are discarded (ضائع کرنا) e.g. dry cell.

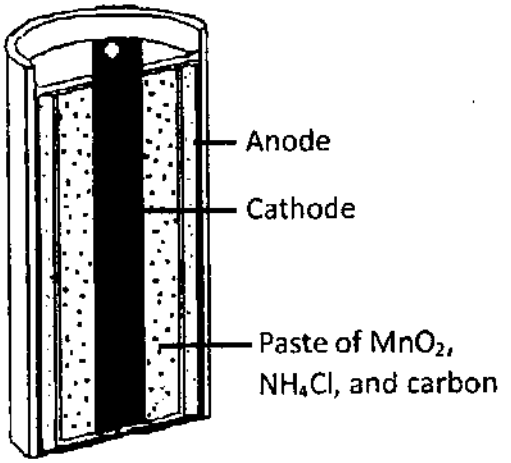
2. **Secondary Batteries:** These are reversible batteries and can be recharged again e.g. lead storage battery.

3. **Solar Batteries:** These are photochemical cells and generate energy.

4. **Fuel Batteries:** These are super batteries and have high energy efficiency.

Dry Cell / Leclanche Cell:

This cell was designed/prepared by George Leclanchi in 1887. So it is also called Leclanchi cell. Dry cell is acidic in nature. It consists of an outer "Zn" casing (خول) which acts as anode. It is lined inside with a moist paper which prevents zinc from coming in contact



Internal Structure of Dry Cell

with the other reactants but allow the diffusion of ions.

A graphite rod is placed in the centre of the container which acts as cathode. The container is filled with a paste of ammonium chloride [NH_4Cl], manganese dioxide [MnO_2] and carbon. The cell is water proofed with wax. The voltage produced by dry cell is 1.25 - 1.50V.

Reactions:

At Anode: Zinc is oxidized by losing the two electrons

$$Zn \longrightarrow Zn^{+2} + 2\bar{e}$$

At Cathode: Ammonium chloride and manganese dioxide are reduced to Mn_2O_3 and NH_3

$$2MnO_2 + 2N^{+}H_4 + 2\bar{e} \longrightarrow Mn_2O_3 + 2NH_3 + H_2O$$

Net reaction:

$$Zn + 2MnO_2 + 2N^{+}H_4 \rightarrow Mn_2O_3 + 2NH_3 + H_2O$$

Q11: Write down a note on electrochemical industry.

Ans. Electrochemical industries are based on many electrochemical operations. Some of these are as follow:

1. Electrochemical cells/batteries constructed between different electrodes are available in the market, which are widely used to power toys (کھلونے), flash lights, electronic calculators, radios, tap-recorders, pacemakers, automobiles.
2. Electroplating of metals is the deposition of

one metal layer on the surface of other metal electrolytically. This is done for the purpose of its durability (پائیداری), beauty and repair.

3. Electrolytic production of metals [e.g. Na] and electrolytic refining of metals [e.g. Cu] are the popular methods for obtaining metals in their pure form.
4. Many important chemicals are manufactured by electrochemical process, e.g. NaOH.

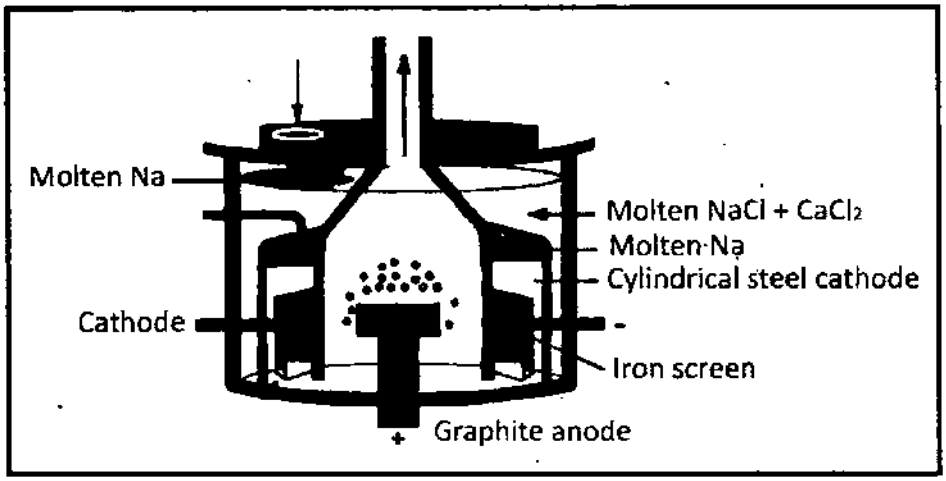
Q12: How sodium metal can be manufactured from fused NaCl?

Ans. **Manufacture of Sodium Metal from NaCl:**

Sodium metal was first discovered by an English chemist, Sir Humphrey Davey in 1807 by the electrolysis of fused NaOH. Commercially sodium metal is obtained by the electrolysis of fused NaCl, in the Down's cell. The electrolytic cell used for the production of metallic sodium was designed by J.C. Down.

Construction of Down's Cell:

The Down cell consists of steel container lined inside with firebricks. The anode is made of graphite at the centre, introduced from the bottom. Above anode there is a dome for the collection of chlorine gas.



The cathode is circular and made of copper or iron. The cathode and anode are separated by an iron screen, to prevent the mixing of the two products of electrolysis namely sodium and chlorine gas. The molten sodium is collected in the cathode compartment where it rises to the top and is taped off (ٹونٹی) through a pipe. Chlorine is collected at anode and is collected from the other pipe.

Reactions in the Cell:

The melting point of sodium chloride [NaCl] is 801C°. A mixture of one mole of NaCl and 3 moles of $CaCl_2$ are used. $CaCl_2$ reduces its melting point to 600C°. When electric current is passed, ions are produced.

$$NaCl \longrightarrow Na^{+} + \bar{C}l$$

The ions move towards the oppositely charged electrodes. Cations (Na^{+}) move towards cathode and anions ($\bar{C}l$) move towards anode.

Chemical Reactions at Electrodes:

$$2NaCl_{(s)} \longrightarrow 2Na^{+}_{(l)} + 2\bar{C}l_{(l)}$$

Anode Reaction:

$2Cl^-_{(l)} \longrightarrow 2Cl$ or $Cl_2 + 2\bar{e}s$ [oxidation]

Cathode Reaction:

$2Na^{+1}_{(l)} + 2\bar{e}s \longrightarrow 2Na$ [reduction]

Overall Reaction:

$2NaCl_{(fused)} \longrightarrow 2Na + Cl_2$

Q13: Explain commercial preparation of NaOH from brine.

Ans. **Commercial Preparation of NaOH:** (Mardan 2017)

Electrolysis of Brine:

30% NaCl solution is called brine solution. Commercially electrolysis of NaCl is carried out in Nelson's cell. Commercially NaOH is prepared by the electrolysis of sodium chloride.

Construction:

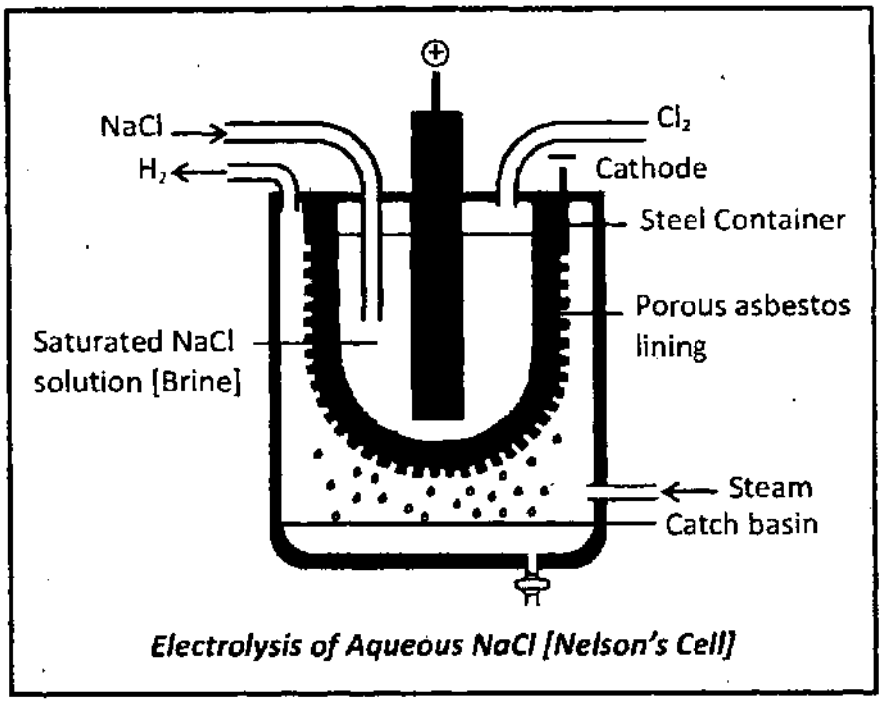
It consists of:

1. Graphite anode
2. U-shaped perforated steel cathode lined inside with asbestos [mixed silicates of Ca and Mg] i.e. $CaSiO_3 \cdot 3MgSiO_3$
3. Rectangular steel tank, having catch basin at the bottom.

Graphite anode is suspended in U-shaped steel cathode having brine solution. The electrolyte used is sodium chloride. Sodium chloride ionizes in water. Water also ionizes to some extent (ω).

$$2NaCl_{(s)} \xrightarrow{H_2O} 2Na^{+}_{(aq)} + 2\bar{C}l_{(aq)}$$

$$2H_2O_{(l)} \longrightarrow 2H^{+}_{(aq)} + 2\bar{O}H_{(aq)}$$



Electrolysis of Aqueous NaCl [Nelson's Cell]

When electrodes are connected to the battery, the positive ions "Na^+ and H^+" move towards cathode. As H^+ ions have greater tendency to pick up electrons from the cathode rather than Na^+ ions, so H^+ ions pick up electrons and form H-atoms. The H-atoms then combine covalently and form H_2-molecules.

At Cathode:

$$2H^{+1} + 2\bar{e}s \longrightarrow H_2 \quad [reduction]$$

Chloride ions ($\bar{C}l$) move towards anode, loses electrons and are converted into chlorine atoms. The chlorine atoms then combine covalently to form chlorine molecules.

At Anode:

$2\bar{C}l \longrightarrow Cl_2 + 2\bar{e}s$ [oxidation]

Then sodium ions combine with hydroxide ions and form sodium hydroxide $2Na^+ + 2\bar{O}H \rightarrow 2NaOH$. Sodium hydroxide is collected in the catch basin. In this process, sodium, hydroxide, hydrogen and chlorine are produced at the same time (ایک ٹکٹ میں تین مزے).

Overall Reaction:

$2NaCl_{(s)} + 2H_2O_{(\ell)} \longrightarrow 2NaOH + H_2 + Cl_2$

Interesting Fact

To separate the chlorine from sodium hydroxide, the two half cells were traditionally separated by a porous asbestos diaphragm (ڈیا), which needed to be replaced every month/two months. This was damaging to the environment as large quantities of asbestos had to be disposed. Asbestos is toxic to humans and causes cancer and lung problems. Today the asbestos is being replaced by other polymers, which do not need to be replaced as often and are not toxic.

Q14: What is corrosion (کارروژن)? Explain with the help of examples.

Ans. **Corrosion:** (BISE Malakand 2018)

Definition: "The slow and continuous eating away of the surface of a metal by the chemicals present in its environment is called corrosion."

Rusting:

"Corrosion of iron is called rusting." Corrosion means the deterioration (ټاټوبړکی) of a metal or its properties because of a reaction with its environment. The terms corrosion and rust are almost synonymous. The word rust is more specifically used for iron. Corrosion usually starts at the exposed surface of the metals. It is an oxidation-reduction process which takes place by the action of air in the presence of moisture with the metals. The common most example of corrosion is the rusting of iron.

Rusting of Iron:

The corrosion of iron is commonly known as rusting.

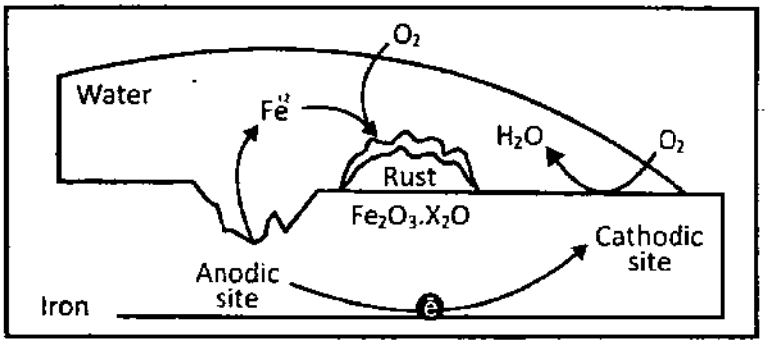
Conditions Necessary for Rusting:

1. Thin film of water/moisture on metal's surface.
2. Air in the environment
3. Weakly acidic atmosphere

Iron rusts, by combining with oxygen in the presence of water to form brown hydrated mass, ferric oxide. $Fe_2O_3 \cdot XH_2O / Fe(OH)_3$

Chemistry of Rusting:

Dents, stains or the impure portion of iron are the sites for the process of rusting.



The impurities or the part of iron which is in contact with ground act as cathode. The pure portion or the aerated part acts as anode. Iron is oxidized at anode, producing ferrous ions [Fe^{+2}] and electrons are lost.

At Anode:

$$2Fe_{(s)} \longrightarrow 2Fe^{+2} + 4\bar{e}s$$

The loss of electrons damages the metals. These free electrons move in the metal sheet to a region of high concentration of oxygen and water near the surface. These sites act as cathode where electrons react with water and oxygen to form hydroxide ion.

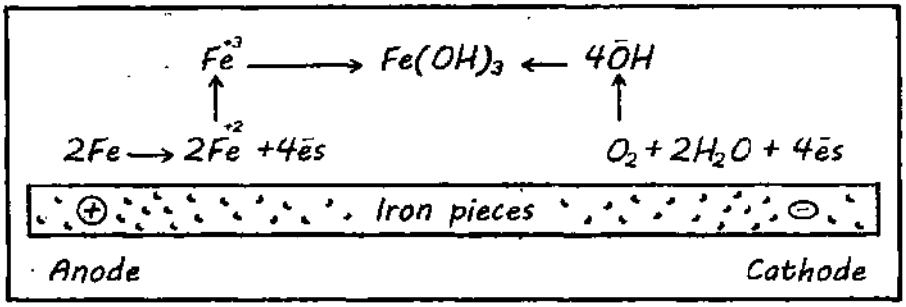
At Cathode:

$$2H_2O + O_2 + 4\bar{e}s \longrightarrow 4\bar{O}H$$

Ferrous ion [Fe^{+2}] is further oxidized to Fe^{+3} by atmospheric oxygen, which form hydrated Fe (III) oxide/hydroxide which is rust.

$$Fe^{+2} \longrightarrow Fe^{+3} + 1\bar{e}$$

$$Fe^{+3} + 3\overset{-1}{O}H \longrightarrow Fe(OH)_3 \rightarrow (rust)$$



Rust is soft and porous (بھربھرا) in nature. Rusting causing agents like oxygen (O_2), CO_2 and moisture can easily pass through it and corrode iron beneath/below it.

Q15: Write down various methods used for the prevention of corrosion.

Ans. **Prevention of Corrosion:** (Abbottabad 2019)

1. **Removal of Stains (دھبے/داغ):**

As the regions of stains in an iron act as the site (جگہ) for corrosion, by removing stains, corrosion can be prevented.

2. **Paints and Coating:**

Coating the metal surface with paint, oil or grease prevents corrosion. Modern paints contain a combination of chemicals called stabilizers. These stabilizers provide prevention against corrosion and other atmospheric effects.

3. **Alloying:**

Corrosion can also be prevented by alloying metals. An example of alloy is stainless steel. Steel is a solid mixture of iron, chromium and nickel. Steel resists corrosion. Similarly brass (پیتل) is an

alloy of zinc and copper.

Alloy: "A homogeneous solid mixture of two or metals or metals and non-metals is called an alloy."

4. **Metallic Coating/Plating:**

"The deposition of a layer of some superior metal over the surface of an inferior metal electrochemically is called electroplating." Metallic coatings or plating is carried out for the prevention of corrosion and also for beautification of metals. A thin coating of one metal on the surface of another metal can be applied by spraying. e.g. galvanizing [deposition of zinc], tinning [deposition of tin] etc. Iron utensils (اشیاء) can be protected from rusting by nickel, chromium or tin plating.

5. **Cathodic Protection:**

This method is used to protect iron in buried fuel tanks (زمین دوز لوہے کی ٹینکیاں) and pipelines. An active metal like zinc or magnesium is connected by a wire to the pipeline or tank to be protected. It is because, zinc and magnesium are better reducing agents than iron. Electrons are supplied by zinc or magnesium instead of iron, thus protect iron from oxidation. As oxidation occurs, zinc/magnesium anode dissolves so it must be replaced periodically (وقتاً). Ship hulls are protected in a similar way by attaching bars [rods] of titanium metal to the steel hull. In salty water titanium act as anode and is oxidized instead of steel hull.

Hull:

The hull is the watertight body of a ship or boat. Above the hull is a super structure and deckhouse.

6. Corrosion inhibitors → Glycerine and polyethylene

Q16: What is electroplating? What is its purpose? Explain the process of electroplating.

Ans. **Electroplating:**

Definition: "The deposition of a layer of some superior metal over the surface of an inferior metal electrochemically is called electroplating."

PURPOSES:

1. **Protection:**

Electroplating is usually done for the protection of a metal from corrosion. For example, nickel and chromium are deposited over the surface of iron to prevent it from corrosion.

2. **Repair (مرمت):**

Used to weld the broken parts of machinery by depositing the layer of metal on it.

3. **Decoration:**

To deposit noble metals like gold, silver and platinum over the surface of an inferior metal to increase its beauty.

Procedure of Electroplating:

First the metallic substance is cleaned with sand, washed with sodium hydroxide solution and water. The cleaned substance is made cathode. A

sheet of pure metal which is to be deposited is made anode. The salt of anode metal is taken as an electrolyte. Electroplating is carried out in a tank of cement, wood or glass. When electric current is passed, metal from anode is deposited on the cathode.

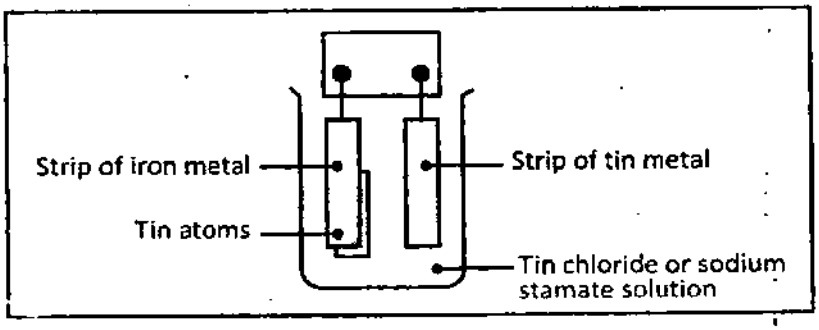
Q17: Write a note on electroplating process of tin [stannum-Sn]

Ans. Electroplating of Tin:

The target metal is cleaned with caustic soda, treated with acids in order to remove the rust, oil and greases present on its surface. Then it is washed with water. Anode is made of tin. Sodium stannate is used as an electrolyte [$Na_2SnO_3 \cdot 3H_2O$]. The substance to be electroplated is made cathode. When electric current is passed through electrolytic solution, anode start dissolving and converted into Sn^{+2} ions. These ions move towards cathode, pick up electrons and deposited in the form of a metallic layer. The following reactions take place:

At anode: $Sn_{(s)} \longrightarrow Sn^{+2} + 2\bar{e}s$

At cathode: $Sn^{+2} + 2\bar{e}s \longrightarrow Sn_{(s)}$ deposited



Q18: Explain electroplating of zinc.

Ans. Electroplating of Zinc: (Mardan 2019)

During this process cleaned zinc metal is made anode. The article to be electroplated is made cathode. $ZnSO_4$ salt and H_2SO_4 solution acts as an electrolyte. Zinc anode dissolves, producing Zn^{+2} and electrons. Zinc ions move towards cathode, pick up electrons and are deposited as zinc metal. Reactions taking place at electrodes are given below:

At anode: $Zn \longrightarrow Zn^{+2} + 2\bar{e}$

At cathode: $Zn^{++} + 2\bar{e}s \longrightarrow Zn$ (deposited)

Q19: Write a note on electroplating of chromium.

Ans. Electroplating of Chromium:

In chromium plating, anode is made of chromium metal. Chromic acid $[H_2CrO_4]$ and H_2SO_4 solution is used as an electrolyte. The article to be electroplated is cleaned and made the cathode. The electrodes are connected to the terminals of the battery. When electric current is passed through the solution, the following reactions taking place:

Anode: $Cr \longrightarrow Cr^{+3} + 3\bar{e}s$ [oxidation]

Cathode: $Cr^{+3} + 3\bar{e}s \longrightarrow Cr$ [reduction]

SOCIETY, TECHNOLOGY & SCIENCE

Pure silver is very soft metal, also called the fine silver. It is relatively soft, very malleable. Silver atoms have weak interactions and are loosely packed together. Silver tarnishes [loss of colour,

dull colour] in air when it comes in contact with trace amount of H_2S or SO_2 in the air and turn blackish. Due to this reason decorative and practical objects which are made of solid silver gradually turns black, and lose their shining appearance. It is easily damaged so it is commonly combined with other metals to produce a more durable product. The most popular of these alloys is sterling silver, which consists of 92.5% silver and 7.5% copper.

To preserve the food and taste of the food, preservatives are added. These preservatives are usually organic acids such as acetic acid and benzoic acids etc or their salts. If the food beverages are canned (ڈبے میں بند کرنا) in iron or in any other corrosive [reactive] metal, these acids will react with cans. It will corrode the cans and will destroy the food and beverages and may form toxic substances by reacting with iron or other reactive metals.

To deal with these problems, food and beverages industries use tin plated steel cans. Tin plating is non-poisonous and prevents corrosion. It also preserves the taste of food and beverages by preventing the reaction with cans.

﴿اقوال حضرت عثمانؓ﴾

- فقیر کا ایک درہم صدقہ بہتر ہے غنی کے لاکھ درہم صدقہ سے۔
- اگر تُو گناہ پر آمادہ ہے تو کوئی ایسا مقام تلاش کر جہاں اللہ تعالیٰ نہ ہو۔

Exercise

Choose the correct option:

1. The oxidation number of N_2 is:
   (a) +1 (b) +3
   (c) 0✓ (d) -3
2. What is the oxidation number of "C" in $\overset{-2}{C}\overset{+3}{H_3}\overset{-2}{O}\overset{+1}{H}$?
   (a) -2✓ (b) -1
   (c) 0 (d) +1
3. A cation is:
   (a) Neutral (b) Negatively charged
   (c) Coloured **(d) Positively charged✓**
4. Electrons are lost by the:
   (a) Reducing agent as it undergoes oxidation✓
   (b) Reducing agent as it undergoes reduction
   (c) Oxidizing agent as it undergoes oxidation
   (d) Oxidizing agent as it undergoes reduction
5. What is the oxidation number assigned to manganese in $KMnO_4$?
   (a) +7✓ (b) +3
   (c) +2 (d) +4
6. In a particular redox reaction, the oxidation number of phosphorus changed from -3 to 0. From this information, it may be concluded that phosphorus:
   (a) Lost 3 electrons and was reduced
   (b) Lost 3 electrons and was oxidized✓
   (c) Gained 3 electrons and was reduces

(d) Gained 3 electrons and was oxidized

7. Which statement is true for an electro-chemical cell?

(a) Oxidation occurs at anode only✓

(b) Reduction occurs at anode only

(c) Oxidation occurs at both the anode and cathode

(d) Reduction occurs at both the anode and cathode

8. In which of the following does sulphur have an oxidation number of +7?

(a) HSO_3^-

(b) SO_3 $\boxed{+2 + 14 - 16 = 0}$

(c) H_2SO_4

(d) $H_2S_2O_8$✓ $\boxed{\begin{matrix} +2 & +14 & -14 \\ +1 & +7 & -2 \end{matrix} \quad H_2\ S\ O_8}$

9. What happens to the reducing agent in an oxidation-reduction reaction?

(a) It is oxidized as it gains electrons

(b) It is oxidized as it loses electrons✓

(c) It is reduced as it gains electrons

(d) It is reduced as it loses electrons

10. In an electrochemical cell, electrons travel in which direction?

(a) From the anode to the cathode through the external circuit✓

(b) From the anode to the cathode through the salt bridge

(c) From the cathode to the anode through

the external circuit

(d) From the cathode to the anode through the salt bridge

Short Questions

Q1: Indicate which element is reduced in the following reactions?

(a) $Ca + Br_2 \longrightarrow CaBr_2$

(b) $8H^{+1} + MnO_4^{-1} + 5\bar{e} \longrightarrow Mn^{+2} + 4H_2O$

Ans.

(a) Bromine is reduced from $Br^0 \rightarrow Br^{-1}$

(b) Manganese is reduced from $Mn^{+7} \rightarrow Mn^{+2}$

Q2: What is the oxidation number of silver on each side of the following equations:

$4Ag + O_2 \longrightarrow 2Ag_2O$

Ans. $Ag^0 \longrightarrow 2Ag_2O$

The oxidation number of silver on the left side is zero because it is in free [elemental] state and its oxidation state on the right side = +1.

Q3: Why NaOH is a strong and NH_4OH is weak electrolyte?
(Mardan 2017, Swat 2019)

Ans. NaOH is a strong electrolyte because it ionizes in its aqueous solution upto maximum extent [84%], while NH_4OH is a weak electrolyte because it ionizes upto limited extent [1.3%] in aqueous solution. NaOH is more ionic than

NH_4OH.

Q4: How to prevent corrosion? Enlist few of the methods.

Ans. Corrosion can be prevented by adapting the following methods:

1. Removal of stains from the metal surface.
2. Coating the metal surface by paint, grease and oil etc.
3. Alloying the metals.
4. Coating the metal surface with another metal by spraying e.g. galvanizing.
5. Use of corrosion inhibitor chemicals such as glycerine and polyethylene etc.
6. Cathodic protection

Q5: Write chemical reactions that occur in Nelson's cell.

Ans. Various chemical reactions occurring in Nelson's cell are as follow:

$$2NaCl \longrightarrow 2Na^{+} + 2Cl^{-}$$

$$2H_2O \longrightarrow 2H^{+} + 2\bar{O}H$$

Anode reaction: $2\bar{C}l \longrightarrow Cl_2 + 2\bar{e}s$

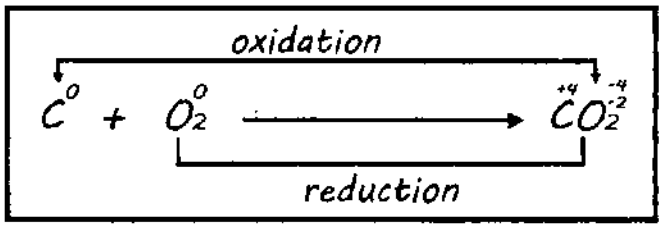
Cathode reaction: $2H^{+1} + 2\bar{e}s \longrightarrow H_2$

$$2Na^{+} + 2\bar{O}H \longrightarrow 2NaOH$$

Q6: Write one example from daily life which involves the oxidation reduction reaction.

Ans.

1. Combustion is an oxidation-reduction reaction in daily life



2. Another example is photosynthesis

Q7: Assign oxidation numbers to each atom in the following compounds: (a) HI (b) PBr_3 (c) $CaCO_3$ (d) H_3PO_4 (e) As_2O_5 (f) H_2SO_4

Ans.

a) HI: H = +1, I = -1

b) PBr_3: P = +3, Br = -1 [3Br = -3]

c) $CaCO_3$: Ca = +2, C = +4, O = -2 [3 O = -6]

d) H_3PO_4:
H = +1 [3H = +3], P = +5, O = -2 [4 O = -8]

e) As_2O_5:
As = +5[2As = +10], O = -2 [5 O = -10]

f) H_2SO_4:
H = +1[2H = +2], S = +6, O = -2 [4 O = -8]

Q8: Why oxygen "O_2" is necessary for rusting?

Ans. We know that rusting is basically an oxidation process and oxygen is necessary for oxidation. Similarly, in rusting process oxygen oxidizes ferrous ion to ferric ion [$Fe^{+2} \rightarrow Fe^{+3} + 1\bar{e}$] and the chemical analysis shows that rust is hydrated iron (III) oxide [Fe^{+3}]. In nut shell oxygen is very necessary for the oxidation of ferrous ion [Fe^{+}] into ferric ion [Fe^{+3}] and conversion of H_2O to $\bar{O}H$ ions.

Q9: Sketch the Daniel cell, labeling the cathode, anode and the direction of flow of the electrons.

Ans. Please see the labeled diagram in question # 8.

Q10: Write down some possible uses of an electrolytic cell.

Ans. Some possible uses of an electrolytic cell are:

1. An electrolytic cell is used for the purification of impure metals.
2. Used for the extraction/separation of elements from their compounds such as Na and Cl can be extracted from NaCl.
3. Used for the electroplating process.
4. Used for the conversion of electrical energy into chemical energy.

Long Questions

Q1: (a) What is electroplating?
(b) Distinguish between the nature of anode and cathode in such a process.

Ans. (a) **Electroplating:** (Bannu 2019)

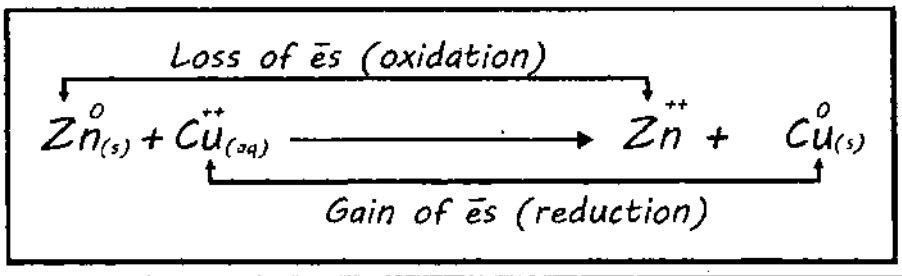
"The process of deposition of a layer of some superior metal over the surface of an inferior metal is called electroplating."

(b) In electroplating process, the substance or article which is to be electroplated is made cathode i.e. will be connected to the negative terminal of the battery. On the other hand, the metal [superior metal] whose layer is to be deposited is made anode i.e. will be connected to the positive terminal of the battery. Simply, inferior (ادنیٰ) metal is used as cathode and superior (اعلیٰ) metal is made anode.

Q2: Differentiate between the process of oxidation and reduction. Write an equation to illustrate each.

Ans. The process during which oxygen is added to a substance, hydrogen is removed from a substance or electron(s) is removed from a substance is called oxidation process while the process during which oxygen is removed from a substance, hydrogen is added to a substance and electron is added to a substance is called reduction process.

Example:



Q3: (a) What is corrosion? Explain rusting of iron as an example of corrosion.
(b) Differentiate between an electrolytic cell and voltaic cell.

Ans. (a) Please see question # 14.

(b) Electrolytic cells are those devices in which electrical energy is converted into chemical energy while in galvanic / voltaic cells a spontaneous redox reaction [chemical energy] generates electrical energy. Simply,

Electrolytic Cell: Convert electrical energy into chemical energy

Voltaic Cell: Convert chemical energy into electrical energy

Q4: Discuss the method of recovering/extracting of metal from its ore.

Ans. "The process of extracting metals from their ores is called metallurgy." The device used for this purpose is electrolytic cell. When an electric current is passed through molten/fused state of the compound, cations move towards cathode and anion move towards anode, pure metal is deposited on cathode.

Lets take the example of extracting sodium from its ore sodium chloride [NaCl]. First a mixture of $CaCl_2$ and NaCl is heated and melted in a furnace at 600C° or pure NaCl is melted at 801C and then electric current is passed through its molten mass. The following reactions/changes taking place.

$$2NaCl_{(s)} \longrightarrow 2Na^{+}_{(l)} + 2\bar{C}l_{(l)}$$

Reaction at anode:

$$2\bar{C}l \longrightarrow Cl_2 + 2\bar{e}s$$

Reaction at cathode:

$$2Na^{+} + 2\bar{e}s \longrightarrow 2Na$$

Q5: Discuss the preparation of sodium hydroxide [NaOH] from brine along with diagram and reactions at cathode and anode.

Ans. Please see question # 13.

❐❐❐